DOCUMENT RESUME

ED 390 654 SE 057 051

TITLE: Science Education: Expanding the Role of Science Departments: Perspectives on Science Education Partnerships, Educational Technology, and Science Program Assessment. Undergraduate Program Directors Meeting (Chevy Chase, Maryland, October 3-5, 1994).

INSTITUTION: Howard Hughes Medical Inst., Chevy Chase, MD. Office of Grants and Special Programs.

PUB DATE: 95

NOTE: 266p.

AVAILABLE FROM: Howard Hughes Medical Institute, Office of Grants and Special Programs, 4000 Jones Bridge Road, Chevy Chase, MD 20815-6789.

PUB TYPE: Collected Works - Conference Proceedings (021)

EDRS PRICE: MF01/PC11 Plus Postage.

DESCRIPTORS: College Faculty; *College School Cooperation; Educational Change; Elementary Secondary Education; Evaluation; Higher Education; *Partnerships in Education; *Science Education; *Teacher Participation; *Technology

ABSTRACT

This report contains the proceedings of the 1994 meeting in which program directors examined issues related to the departmental and faculty involvement in precollege and outreach activities, teacher development, educational technology, assessment, and curricular reform. The keynote address, "The Two Cultures Revisited: Science and Mathematics as the New Liberal Arts", was presented by Sheila Tobias. Session I, "Partnerships for Enhancing Science Teaching," included the following presentations and panel discussions: "Strategies to Involve Faculty Members in Precollege and Outreach Programs"; "The Role of Science Departments in In-Service Science Education"; "Preparing Tomorrow's Science Teachers"; and "Programs for Community College Faculty and Students." Section II, "The Role of Educational Technology in Broadening Access to Science," included the following "Educational Technology: Supplementing Laboratory Instruction" and "Educational Technology Demonstrations." Section III, "Assessing Science Education Programs," included the following presentations and panel discussions: "Overview of Assessment Strategies"; "Student Tracking in Research and Prefreshman Programs"; "Curricular Reform: How Well Is It Working?"; and "Assessing Outreach Programs." The report also contains the profiles of the programs whose directors were featured as speakers. (JRH)

Science Education: Expanding the Role of Science Departments

Undergraduate Program Directors Meeting

Science Education: Expanding the Role of Science Departments

Perspectives on Science Education Partnerships, Educational Technology, and Science Program Assessment

Undergraduate Program Directors Meeting

October 3–5, 1994

Undergraduate Biological Sciences Education Program
Office of Grants and Special Programs

About This Report

In the fall of each year, the Howard Hughes Medical Institute convenes a meeting of directors of the programs supported by grants from the Institute's Undergraduate Biological Sciences Education Program. The purposes of the meeting are to provide a forum for the program directors to discuss various educational challenges facing undergraduate science departments, and to learn how their colleagues in other institutions are addressing those challenges.

Each meeting is organized around a central theme, with plenary and panel sessions devoted to topics within that theme. The focus of the 1994 meeting is Science Education: Expanding the Role of Science Departments. The program directors examined issues related to the departmental and faculty involvement in precollege and outreach activities, teacher development, educational technology, assessment, and curricular reform. Past meeting themes have included Institutional Strategies for Enhancing Undergraduate Science Education *(1993);* Enriching the Undergraduate Laboratory Experience *(1992); and* Attracting Students to Science: Undergraduate and Precollege Programs *(1991).*

This report contains the proceedings of the 1994 meeting, plus profiles of the programs whose directors were featured as speakers.

The contributions of Sarah Brookhart, W. T. Carrigan, Miriam Davis, Ph.D., Jeffrey L. Fox, Ph.D., Jeff Malter, Hugh McIntosh, Jeff Porro, and Frank Portugal, Ph.D., to this report are gratefully acknowledged.
The photographs in Part I were taken by William K. Geiger.

The names of colleges and universities are listed as they appear in the *1995 Higher Education Directory.*

Contents

Howard Hughes Medical Institute

vii Biomedical Research Program

vii Grants and Special Programs

ix Undergraduate Biological Science Education Program

Preface and Introduction

xi Preface

xv Introduction: The Changing Role of Faculty in Undergraduate Science Education

Program Overview

1 Undergraduate Program Overview

Part I

Proceedings of the 1994 Program Directors Meeting

Monday, October 3, 1994

Keynote Address

13 The Two Cultures Revisited: Science and Mathematics as the New Liberal Arts
Sheila Tobias

Tuesday, October 4, 1994

Session I: Partnerships for Enhancing Science Teaching

Plenary Presentation 1

23 **Strategies to Involve Faculty Members in Precollege and Outreach Programs**
Xavier University of Louisiana - Deidre Labat, Moderator: Jacqueline Hunter, JW Carmichael

Panel Discussions

28 **Group 1—The Role of Science Departments in In-Service Science Education**
Panel Members: Smith College - Thomas S. Litwin, Casey Clark
University of Colorado at Boulder - Mark William Dubin, Julie Graf
University of Wisconsin–Madison - Paul H. Williams, Moderator: Andrew J. Petto

34 **Group 2—Preparing Tomorrow's Science Teachers**
Panel Members: Oberlin College - David Benzing, Dennison Smith
State University of New York at Binghamton - Anna Tan-Wilson, Herbert Posner
University of Nebraska–Lincoln - Eric Davies, Moderator: David T. Crowther

41 **Group 3—Programs for Community College Faculty and Students**
Panel Members: Arizona State University - James Collins, Steven W. Rissing
University of California–Davis - Merna Villarejo, Moderator: Mark G. McNamee
City University of New York City College - Sharon Cosloy, Joseph Griswold

Session II: The Role of Educational Technology in Broadening Access to Science

Plenary Presentation 2

47 **Educational Technology: Supplementing Laboratory Instruction**
Panel Members: Beloit College - John Jungck, Moderator
Harvard University - Stephen C. Harrison, Scot A. Wolfe
University of Puerto Rico Mayaguez Campus - Juan González-Lagoa, Juan López Garriga

53 **Educational Technology Demonstrations**

Wednesday, October 5, 1994

Session III: Assessing Science Education Programs

Plenary Presentation 3

59 **Overview of Assessment Strategies**
Panel Members: University of Arizona - Michael A. Wells, Carol Bender
University of California–San Diego - Gabriele Wienhausen, Barbara Sawrey
Wellesley College - Mary Mennes Allen, Moderator; R. Steven Schiavo

Panel Discussions

65 **Group 1—Student Tracking in Research and Prefreshman Programs**
Panel Members: Tuskegee University - J.H.M. Henderson
University of Michigan–Ann Arbor - Sandra Gregerman, Michael M. Martin
Williams College - Steven J. Zottoli, Moderator; Daniel V. Lynch

71 **Group 2—Curricular Reform: How Well Is It Working?**
Panel Members: Bates College - Martha A. Crunkleton, Pamela Baker
Carnegie Mellon University - Susan Henry, William E. Brown
University of California–Los Angeles - Frederick A. Eiserling, Moderator; Orville Chapman

76 **Group 3—Assessing Outreach Programs**
Panel Members: North Carolina State University - William C. Grant, Moderator; Sarah Berenson
University of Chicago - Robert L. Perlman, Anne M. Heinz
Villanova University - R. William Marks, William M. Fleischman

Plenary Review

83 **Summary of Key Issues**
John Jungck, Mary Mennes Allen, Deidre D. Labat
Joseph G. Perpich

Part II
Program Profiles

91 **Programs at a Glance: Overview of 1994 Meeting Participants by Activity**

92 **Partnerships for Enhancing Science Teaching**

141 **The Role of Educational Technologies in Broadening Access to Science**

156 **Assessing Science Education Programs**

Appendices

223 A: Attendees, Program Directors Meeting, October 3–5, 1994

226 B: Awardee Institutions by Carnegie Classification, 1989–1994

230 C: Awardee Minority Institutions, 1989–1994

231 D: Awardee Institutions by State, 1989–1994

Grants Publications

235 Grants Publications

Howard Hughes Medical Institute

237 Trustees

238 Officers

239 Principal Staff Members

240 Office of Grants and Special Programs

Index

241 Index

The Howard Hughes Medical Institute was founded in 1953 by aviator-industrialist Howard R. Hughes. Its charter, in part, reads:

The primary purpose and objective of the Howard Hughes Medical Institute shall be the promotion of human knowledge within the field of the basic sciences (principally the field of medical research and medical education) and the effective application thereof for the benefit of mankind.

Biomedical Research Program

The Howard Hughes Medical Institute is a nonprofit medical research organization dedicated to basic biomedical research and education. Its principal objectives are the advancement of fundamental knowledge in biomedical science and the application of new scientific knowledge to the alleviation of disease and the promotion of health. Through its program of direct conduct of medical research in conjunction with hospitals, the Institute employs approximately 280 independent investigators who conduct research at its laboratories in 64 leading academic medical centers, hospitals, and universities throughout the United States. The Institute conducts research in five broad areas: cell biology and regulation, genetics, immunology, neuroscience, and structural biology.

To aid these research efforts, the Institute is involved in the training of graduate and postgraduate students in its investigators' laboratories, has given substantial support to the international genome mapping program, provides research training to medical students through the Research Scholars Program (conducted jointly with the National Institutes of Health), and organizes scientific conferences, workshops, and program reviews.

Grants and Special Programs

To complement its research program, the Institute has launched a grants program dedicated to strengthening education in the biological and related sciences. This program is administered by the Office of Grants and Special Programs and is designed to enhance science education at the graduate, undergraduate, and precollege levels; to increase public understanding and appreciation of science, and to support fundamental biomedical research abroad. In addition, a comprehensive assessment effort is under way. The Institute grants reach a wide range of institutions involved in formal and informal science education, including colleges and universities, medical schools, elementary and secondary schools, research centers, and museums.

The goal of the Institute's undergraduate science education program is to strengthen the national quality of college-level programs in the biological sciences and other scientific disciplines as they relate to biology, and to attract and retain students in scientific research and education careers. Under this program, grant awards are made to colleges and universities in support of student research and other opportunities in the sciences, for equipment and laboratories, for faculty and curricular development, and for outreach programs. The purpose of the latter is to link colleges and universities with elementary and secondary schools, community colleges, and other institutions in order to promote science and mathematics education. To date, the Institute has awarded $290 million in grant support to 213 colleges and universities in six previous rounds of competition (1988–1994).

A primary objective of the Institute's graduate program is to contribute to the continued strength and quality of the nation's pool of biomedical research scientists by supporting opportunities for training in research. Graduate support is principally for fellowships awarded under three programs, each representing a different level of graduate study in biological sciences. Fellowships are available for predoctoral students in biological sciences, for selected medical students, and for physician-scientists at early stages of their professional careers.

Under the Institute's precollege science education initiative, grants totaling $6.4 million were awarded in 1992 to 29 museums to interest children, their teachers, and families in science and to improve general scientific literacy. In 1993, $4.3 million was awarded to 22 zoos, aquaria, and botanical gardens to strengthen their science education outreach. In 1994, a total of 42 medical schools and research institutions received $10.3 million in grant support for outreach in the sciences to local and regional schools.

The Institute's research resources program has provided support to research organizations serving as unique national resource laboratories and teaching facilities. A research resources program for medical schools is a new grants initiative. The primary objective of the latter program is to foster the research activities of schools of medicine by strengthening their research infrastructure and by promoting the early careers of their basic and clinical science faculties. This new program has been established to provide a flexible support for investigator-initiated research in the nation's medical schools, where many of the pivotal advances in our fundamental knowledge of biological processes and disease mechanisms have occurred.

In recognition of the important contributions of scientists abroad to advances in biomedical science, the Institute has also launched a limited experimental program to support the research of a small number of selected biomedical investigators in other countries.

Undergraduate Biological Sciences Education Program

The purpose of this program is to strengthen the national quality of college-level education in the biological sciences and other scientific disciplines as they relate to biology. Another important objective is to support outstanding programs that seek to attract and retain students in scientific fields, including women and members of minority groups underrepresented in the sciences.

Colleges and universities are invited to compete for undergraduate grants on the basis of their recent records of having graduated students who went on to matriculate in medical school or to earn a Ph.D. in biology, chemistry, physics, or mathematics.

The Institute encourages institutions to develop programs that respond to their particular strengths and needs. In the current program phase, grants are awarded in support of student research and broadening access programs; equipment and laboratory development; and outreach programs linking science departments with community colleges, elementary and secondary schools, and other institutions.

In the area of student research and broadening access, the Institute enables students to engage in summer and academic-year laboratory experiences on and off campus. It supports prefreshman bridging programs, laboratory training, opportunities for students to present their research at scientific meetings, and other activities that promote a culture of science at the undergraduate level. It supports efforts to enhance education in biology, integrate it with other disciplines, and modernize teaching laboratories through renovation and equipment acquisition. Science outreach programs for faculty members, teachers, and students at community colleges and secondary and elementary schools are also supported.

In 1988, 34 liberal arts and comprehensive colleges and 10 historically black institutions were awarded \$30.4 million for their science programs. In 1989–1990, 51 research and doctorate-granting universities received \$61 million to enhance undergraduate science education. In the third round, completed in 1991, 44 additional liberal arts, comprehensive, and minority institutions were awarded \$31.5 million in grant support. In 1992–1993, 42 additional research and doctorate-granting universities were awarded \$52.4 million. In the fifth competition, completed in 1993, a total of 47 liberal arts, comprehensive, and minority institutions received $28.5 million. In a sixth competition, held in 1994, 62 research and doctorate-granting universities were awarded four-year grants totaling $86 million.

Preface

Purnell W. Choppin, M.D. ■ President ■ Howard Hughes Medical Institute

The Howard Hughes Medical Institute is primarily a medical research organization employing about 280 distinguished scientists in some of the nation's leading medical centers, hospitals, and universities. Its grants program component is more like a traditional foundation. Since its creation in 1987, the program has been an important part of the Institute. It has launched the largest private science education initiative in U.S. history, with a total of $323 million in grants, including $52.5 million in 1994. The largest portion has been awarded to undergraduate science departments to expand research opportunities for students, modernize course offerings and facilities, and encourage women and underrepresented minorities to pursue scientific careers. Colleges and universities also use Institute funding for outreach programs to students and science teachers at local schools.

HHMI President Dr. Purnell W. Choppin welcomes the undergraduate program directors and opens the meeting with a brief history of the Institute's grants programs.

The premise on which the grants program was founded remains as true today as when it began, and will always be true: investment in science education is essential to ensure the future strength of biomedical research. But science education itself has changed a great deal even in that relatively short time. This is particularly so at the undergraduate level, which is the focus of this report.

Several basic assumptions guide the Institute's science education initiatives at all levels, including the undergraduate grants program.

- ■ Students learn science best by doing science
- ■ Science education at the preprofessional level should resemble a pump more than a filter
- ■ The scientific community must play an active role in improving science education
- ■ We in the scientific community must foster a commitment to excellence, demanding great things not only from students, teachers, and schools, but also from ourselves.

Another basic truth about research permeates the activities of the undergraduate program: that research is an inherently collaborative enterprise, requiring people and institutions to form partnerships, whether their goal is to make scientific discoveries that will improve society or to increase student participation in biology and physics. The old movie stereotype of the lone scientist feverishly toiling in his (yes, it was always "his") lab, his genius manifested in a slightly crazed look, was never realistic, but without better science education of all kinds, it may continue to be the scientist's public image. In reality, science is a team effort. Similarly, science education should be a team effort, involving faculty, administrators, students, and the wider scientific and educational communities.

Student Research

One of the most important areas that HHMI supports at the undergraduate level is the direct conduct of research by students, because science is best learned by doing. Several of the programs participating in the 1994 undergraduate program directors meeting offer such research opportunities, and it is clear that faculty commitment is the critical factor.

The Institute's strong interest in encouraging women and underrepresented minorities in science is also reflected in these activities and many other undergraduate science education projects funded by HHMI grants. Smith College, for example, has developed a program aimed at drawing girls and young women into science by training the people who are the most influential in shaping student careers—science teachers and school counselors—both in the substance of science and in the issues that deter female participation. Those issues include peer pressure, a lack of role models, unequal treatment in the classroom, and ineffective career counseling. Several other examples are discussed in this meeting report.

The Shape of Things to Come

The terms and circumstances of human existence can be expected to change radically during the next human life span. Science, mathematics, and technology will be at the center of that change—causing it, shaping it, responding to it. Therefore, they will be essential to the education of today's children for tomorrow's world.[1]

Professional researchers today have awesome tools at their disposal, including access to unprecedented amounts of data and the ability to analyze it. Powerful database technologies, as well as an impressive array of other electronic aids, are being used in undergraduate classrooms and teaching laboratories. As noted by Dr. Stephen Harrison, HHMI Investigator and Professor of Biochemistry and Molecular Biology at Harvard University, computer graphics allows instructors to transcend the old physical models. Now science faculty can show students complex structures at atomic levels, and demonstrate their biological, chemical, and physical properties.

Beloit College's BioQUEST program uses computer-based instructional programs to provide research opportunities to freshman and sophomore students and prepare them for the challenges of upper-division science courses. At the University of California–San Diego, students are developing critical laboratory skills using an interactive multimedia computer manual in the introductory Biochemical Techniques course. The flexibility of these programs permits students to learn at their own pace and to continue their investigations beyond the laboratory setting.

The increasing presence of technology in science education has enormous implications for undergraduate curricula as faculty from a variety of disciplines collaborate in the development of instructional software. It also has the potential to bring teaching and research closer together through enhanced student research activities and exposure of nonscience majors to high-quality science instruction.

HHMI-supported educational technologies include software applications, many of them "multimedia," in molecular biology, genetics, structural biology, physics, mathematics, biochemistry, and other disciplines. The Institute also supports computer bulletin boards and electronic networks for teachers and students at the elementary, secondary, and undergraduate levels. The merger of computers and science has been taken a step farther at Carnegie Mellon University, which now offers an interdisciplinary curriculum in computational biology designed to meet the growing demand for scientists with advanced computer skills.

As teachers experiment with educational technologies and new curricula to enhance teaching and student learning, it is important to understand what students respond to, what teaching methods work, and what impacts follow such activities as mentoring and precollege exposure to science.

Assessing the effectiveness of innovative educational approaches like those being developed by HHMI grantees requires complex planning and data collection strategies. Student tracking is in progress at several institutions. For example, Wellesley College is conducting a longitudinal study, called Pathways for Women in Science, that tracks the academic and career paths of 538 members of the class of 1994. The evaluation began when the women registered for courses and followed them as they took science courses, selected majors, and graduated. The study will also follow them after college.

Involving students in research early in their academic career has an intuitive appeal as a way to improve student academic performance and inspire the kind of interest in science that is desirable in science majors and nonscience majors alike. The undergraduate research program at the University of Michigan–Ann Arbor includes an extensive evaluation component that can discern whether participating in the program really does encourage students to take more rigorous science courses and can determine the specific effects of different aspects of the program. The university's evaluation includes a study of faculty attitudes to see if the program increases their interest in teaching, or otherwise shapes their approaches to students, especially women and underrepresented minorities.

Increased Roles and Responsibilities

The nation's colleges and universities are assuming (and being expected to assume) an ever-increasing set of roles and responsibilities. Even just a partial list of these...would include serving as a think tank, a government and corporate research arm, a small business incubator, a technology-transfer mechanism, a promoter of economic development, and numerous other functions in addition to the core teaching responsibilities of the institution....What is most important...is that institutions pursue (and be allowed to pursue) these activities in ways that enhance learning experiences for students and further the teaching mission of higher education.[2]

HHMI is committed to helping the nation's colleges and universities provide high-quality science programs and related activities to a diverse student population. The 1994 meeting of the undergraduate program directors was a lively exchange of ideas and information about achieving these objectives. This meeting report provides an informative overview of the creative approaches that are being developed and implemented with the grants that have been provided. And it examines in greater detail the directors' discussions about the roles of partnerships, computer technology, and assessment in improving science education at the undergraduate level.

References

1. American Association for the Advancement of Science. *Science for All Americans*. Project 2061, cover. Oxford, New York, Toronto: Oxford University Press, 1990.
2. Good, Mary L., and Neal F. Lane. "Producing the Finest Scientists and Engineers for the 21st Century." *Science* 266:741, Nov. 4, 1994.

The Changing Role of Faculty in Undergraduate Science Education

Joseph G. Perpich, M.D., J.D. ■ Vice President for Grants and Special Programs

HHMI Undergraduate Biological Sciences Education grants fund activities that reflect the direct needs of undergraduate science programs as well as broader objectives in science education. With Institute support, science faculty from a range of public and private institutions throughout the nation—research universities, liberal arts colleges, and historically black institutions—are developing and implementing initiatives to attract students to science, particularly women and underrepresented minorities; updating curricula and enhancing faculty; producing an array of educational and instructional technologies; improving teaching laboratories; and bringing science to precollege students, again with emphasis on young women and minorities.

Since 1988 the Institute has awarded \$290 million in grant support to 213 colleges and universities for undergraduate science education. In October 1994 the latest competition gave 62 colleges and universities a total of \$86 million in undergraduate science education grants.

Each fall the Institute convenes a meeting of the program directors at these institutions. The purpose is to provide a forum for discussion of educational challenges facing undergraduate science departments and of how they are being addressed. This meeting is one of five held annually by the grants program at the Institute conference center in Chevy Chase, Maryland. The others bring together, respectively, medical student fellows, predoctoral and physician postdoctoral fellows, directors of precollege and public science education programs, and high school students in the Washington, D.C., metropolitan area who participate in local Institute-supported activities.

Each program directors meeting is organized around a central theme, with plenary and panel sessions devoted to topics within that theme. The focus of the 1994 undergraduate meeting was expanding the role of science departments. The program directors examined issues related to departmental and faculty involvement in precollege and outreach activities, teacher development, educational technology, assessment, and curricular reform. The discussions evoked some compelling observations about the current climate for science education at the undergraduate and precollege levels.

Changes in Science

Fundamental changes are taking place in science at a breathtaking pace and reverberating through the nation's undergraduate science departments. Research uni-

Ms. Tobias, Dr. Joseph G. Perpich, HHMI Vice President for Grants and Special Programs, and Ms. Casey Clark of Smith College continue the discussion of issues raised by Ms. Tobias in her keynote address.

At UCLA the blurring of interdisciplinary boundaries has resulted in more than 100 faculty from 11 departments reorganizing themselves into "research affinity" groups, none named after an existing department. Instead, faculty now describe themselves in terms of their research interest—cell biology, immunology, genetics.

versities must continually incorporate massive amounts of new knowledge into their curricula and adjust to shifts in disciplinary boundaries. As with science in general, undergraduate departments must realign in order to accommodate evolving interdisciplinary collaboration, expanded use of educational technology, new partnerships in outreach and recruitment programs, and widespread curriculum revisions.

There are significant external changes as well: shrinking government funding, changes in student demographics, and increased public pressure for science to address health and environmental issues. The end of the Cold War is having enormous repercussions throughout the academic research enterprise, and in many disciplines scientists must compete for a diminishing share of federal research support. However, in biology, as Dr. Harold Varmus, director of the National Institutes of Health, has observed, "Our enemy is still there."

Creative Approaches

To operate day-to-day in this climate of substantive, structural, and environmental change is a constant challenge. At the same time, undergraduate science faculty and deans are accepting new roles in such areas as expanding the science literacy of the general population and improving access to science and higher education for women and underrepresented minorities. Balancing these needs with educational and administrative demands was a universal concern for the departments represented at the 1994 meeting. It became apparent, however, that this era of change has inspired an array of creative approaches.

At the University of California, for example, severe state budget cutbacks have led to the loss of hundreds of faculty and widespread changes in departmental structures throughout the university system. The cutbacks have directly affected science education at UCLA, where there will be at least a 10-percent reduction in faculty and a 20-percent reduction in budget from 1990 levels. In the process of absorbing these reductions, several life sciences departments have consolidated recruitment and advisory activities, sought private-sector funding for laboratory and computer equipment, and formed stronger alliances with the medical school.

Beyond issues of administrative efficiency, critical educational reorganizations are occurring in the way science is taught. Again at UCLA the blurring of interdisciplinary boundaries has resulted in more than 100 faculty from 11 departments reorganizing themselves into "research affinity" groups, none named after an existing department. Instead, faculty now describe themselves in terms of their research interest—cell biology, immunology, genetics.

Undergraduate curricular units at UCLA are based on faculty expertise rather than departmental location. Among the results are improved introductory courses that convey recognition of the fact that many science students will not become scientists, but need a broader understanding of science for responsible citizenry. Changes like those at UCLA will make both graduate and undergraduate science faculty more receptive to interdisciplinary science instruction and more broadly trained science graduates.

"Two Cultures," Multiple Constituencies

As we have seen in several institutions, curriculum reform is taking place not just to accommodate new developments in science but also greater diversity in student populations. In her keynote address, Sheila Tobias talked about the need to overcome a mutual disdain between the "two cultures" of science and the humanities. The phrase was coined decades ago by renowned British physicist and writer C.P. Snow. The gulf between the two cultures, in Tobias's view, has been created in part by an elitist tendency in science, which has served to "weed out" students.

Mathematics and science are presented as a set of skills to be mastered, Tobias said, rather than bodies of knowledge that have historical and philosophical contexts. This is more in keeping with the approaches in the humanities. Too many college students have negative experiences with their science courses, leaving them with a lasting fear or dislike of science. Tobias echoes Snow's message that edu-

"The way to make mathematics and science part of the liberal arts is /to think of them/ as increasing the stickiness and the surface area of the student's mind itself so that, with every passing year, there is more sticky stuff in place, more yearning to know, and more capacity to learn....Some call it my 'flypaper theory' of education."

— Sheila Tobias

"It's really no different than being involved in Little League. Many kids enter, but only a few become athletes. It's the same with this program—maybe only a few will go on in science, but at least they've had the experience."
—Joe Mims

"What telemarketing and phone banks did for catalog sales, what QVC did for home shopping, what ATMs did for banking, the information highway is about to do for distance learning and higher education."
—Pew Higher Education Roundtable

cators in both cultures must help bridge the gap.

She gives Snow's message a new sense of urgency with her observations about the increase in antiscience sentiments in recent years. "The way to make mathematics and science part of the liberal arts is [to think of them] as increasing the stickiness and the surface area of the student's mind itself so that, with every passing year, there is more sticky stuff in place, more yearning to know, and more capacity to learn....Some call it my 'flypaper theory' of education."

Dr. Robert Hazen, research scientist at the Carnegie Institution of Washington, and keynote speaker for the 1993 precollege meeting, had expressed a similar view. He stressed that science education must serve two different kinds of students: "future scientists" and "future citizens." There is need for a broader approach to science education so that "the remaining 99 percent of students [who do not go into science] learn the basic scientific concepts that would help them understand a wide range of issues that affect their lives." This new approach is particularly beneficial in designing courses to present information in ways that accommodate individual learning styles and encourage participation by women and underrepresented minorities who may lack appreciable precollege exposure to science.

Joe Mims, a city parks and recreation superintendent in Sacramento, commented on the value of the community science program operated by the Discovery Museum–Learning Center with an HHMI grant. "It's really no different than being involved in Little League. Many kids enter, but only a few become athletes. It's the same with this program—maybe only a few will go on in science, but at least they've had the experience."

Educational Technology

One of the most promising areas for improving access to scientific information is the proliferation of computer-assisted materials for teaching science. In 1995 the HHMI undergraduate program is reviewing the development of educational technology by its grantees.

In a related initiative, Drs. Sondra Lazarowitz and Roy Roper, of the University of Illinois at Urbana–Champaign, have created an electronic network for the HHMI undergraduate science education program. A bulletin board for communication among the undergraduate programs, and two "drop-box" addresses with the electronic equivalent of file folders, allow programs to post information about their educational technologies. The network was established in response to several requests for a central repository so that each institution is not "reinventing the wheel" as it incorporates the new technologies into its curriculum.

In the context of innovations in educational technologies, Dr. Alan E. Guskin, Chancellor of the Antioch University System, advanced a view of the future inspired by current trends. "Courses as we now know them may be radically altered so that a student would learn a particular subject area in a series of 'learning blocks,' with one block focused on electronic sources, another on intensive interaction with a faculty member, a third on intensive lecture-discussion formats over brief periods of time, a fourth in real-life experiences or simulations, and even another block as a peer study group."

The revolution in educational technology raises a number of issues of access, not only providing computer labs at all hours, but also having to do with different learning styles and equity. As Dr. Deidre Labat of Xavier University of Louisiana, puts it, "Teachers have one teaching style; students have different learning styles."

How these may be accommodated is indicated in a publication of the Pew Higher Education Roundtable: "What telemarketing and phone banks did for catalog sales, what QVC did for home shopping, what ATMs did for banking, the information highway is about to do for distance learning and higher education."

Educational technology has the potential to respond to a variety of learning styles. But there must be a close watch to ensure that access is expanded, not narrowed, and that educational software and publications are responsive to students' individual needs. In keeping with its goal of encouraging more women and minorities to enter science, the Institute's review of educational technologies will encompass such issues, with special emphasis on broadening the access to educational technology for a diverse audience.

A New Language

Cyber-surfing, Mosaic, FTP, World Wide Web, gopher, home page, URL, zorch, virtual reality, CD-ROM, hypertext....Your experience—and comfort level—with this cryptic new language probably depends on how many trips you've taken on the information highway. An exploding vocabulary is just one aspect of the new intergenerational divide, but there are profound implications in the rapidly increasing familiarity with technology among those who will soon be students in undergraduate science departments.

The BioQUEST Carriculum Consortium at Beloit College is in the vanguard of the educational technology expansion. The consortium's director, Dr. John Jungck, reminds us that *learning*

"Courses as we now know them may be radically altered so that a student would learn a particular subject area in a series of 'learning blocks,' with one block focused on electronic sources, another on intensive interaction with a faculty member, a third on intensive lecture-discussion formats over brief periods of time, a fourth in real-life experiences or simulations, and even another block as a peer study group."

—Alan E. Guskin

"Scholarship and publications... signal to the world an excellent faculty and, by implication, an excellent school.... The great undergraduate course, in sharp contrast, gets local kudos—not national acclaim—so it can have only narrow impact on the school's or the teacher's reputation."
—Gordon C. Winston

is the mission at hand and we must not be distracted by the technology's dazzle.

A great deal is known about the way young people learn from the perspectives of cognition and memory. But there are social factors to be reckoned with. How do you get the attention of young people who have grown up with computers and other technology? People who were raised on "high-tech" toys and multimedia fairy tales take advanced technology for granted. Science education must match this level of sophistication to attract and keep the interest of these students, who will succeed the post-boomer generation.

At the University of California–San Diego, Drs. Barbara Sawrey and Gabriele Wienhausen have advanced undergraduate science teaching and learning through educational technology. With HHMI support, they are developing an interactive manual on biochemical techniques that uses a series of multimedia modules to help prepare students for the laboratory. Components include interactive computer simulations of experiments, modules to teach library skills for preparation of lab reports, electronic mail exchanges with instructors, and an on-line map showing the connections between laboratory techniques, calculations, and classroom topics.

According to Dr. Wienhausen, the program shows the connections between biology and other areas of science in ways that allow students to interrelate concepts. Without this kind of vision, she says, information remains a collection of trivia—data with no unifying theme.

New Roles for Faculty

A number of factors—the educational technology "wave," changes in the economy, changes in student demographics—have created a new reality for undergraduate faculty. Profound questions are being raised about the faculty's role in student learning. Alan Guskin believes that their role must change drastically."The primary learning environment for undergraduate students, the fairly passive lecture-discussion format where faculty talk and most students listen, is contrary to almost every principle of optimal settings for student learning.... Intimate faculty-student contact that encourages feedback, that motivates students, and that allows students to perform is the exception, not the norm."

Guskin summarizes the basic challenge for faculty members: "to integrate the new world of simulation and interactive technologies with their own unique role as mentor, coach, facilitator, and teacher of student learning."

Dr. Jungck put it even more succinctly at the program directors meeting. Undergraduate science faculty must change from being the "sage on the stage" or the "guide on the side" to collaborative researchers and mentors.

In the long run, science faculty stands to gain in personal stature, despite the pervasive truth of Gordon Winston's observation in his essay "The Decline in Undergraduate Teaching—Moral Failure or Market Pressure?" "Scholarship and publications...signal to the world an excellent faculty and, by implication, an excellent school....The great undergraduate course, in sharp contrast, gets *local* kudos—not national acclaim—so it can have only narrow impact on the school's or the teacher's reputation." Both teachers and students should benefit from faculty's more interactive role.

The HHMI undergraduate grants program will continue to examine the role of the faculty as more colleges and universities embrace innovations in precollege science education. During the 1994 meeting, faculty involvement emerged as one of the most common and difficult challenges facing the program directors. There was clear agreement that faculty must recognize an obligation for improving precollege science education, but there was little consensus about ways to increase their participation beyond the sense that internal cultural changes are needed.

Faculty Involvement in Precollege Education: The Xavier Experience

At some institutions, administrators are examining precollege activities during tenure and promotion reviews. At others, faculty are leading the way. The exemplary precollege science education program at Xavier University of Louisiana was founded by faculty from the biology and chemistry departments. Xavier is a private historically black institution, where more than half of the 3,000 students are science majors. In 1994, 157 graduates went on to graduate school or to research, teaching, or other professions. With HHMI support, the university operates four precollege programs, three of which are taught by professors with the assistance of undergraduates. The fourth is taught with high school teachers.

Fifteen years ago Xavier faculty began to seek ways to increase the number of African American students in the health professions. They created a program to address a specific obstacle for high school students, namely a lack of analytical skills. The result was SOAR (Stress on Analytical Reasoning). Next, using this program as a model, other programs were established to help students learn skills and principles in biology, chemistry, and mathematics. With HHMI support, the univer-

One of the central questions in assessment is, How do we measure success in science education efforts? Is it strictly the training of scientists, or is it the preparation of an educated citizenry? As Dr. Steven Zottoli of Williams College expressed it, "Do you want M.D.'s and Ph.D.'s or more scientifically literate lawyers as well?"

sity was able to expand these programs and link them in a kind of sequence that students could move through over a period of years. These programs are featured in a video entitled "The Xavier Experience," which is available from the Institute's communications department.

One other approach bears mention. Several institutions are forming crossdisciplinary organizations for faculty who are interested in science education. At Xavier the Science Education and Research Group (for science and mathematics faculty) is the spearhead of precollege and curricular reform efforts. A similar group has been formed at the University of Arizona.

Professor Paul Williams reported that there are 800 biologists in six departments at the University of Wisconsin–Madison, but there is no department of biology and therefore no single resource for science education efforts. The solution, which was supported by Dr. Donna Shalala, then Chancellor at Wisconsin and now Secretary of the U.S. Department of Health and Human Services, was to form a Center for Biology Education, which operates summer institutes and regional networks for science teachers. Dr. Williams noted that the center cannot compel university faculty to participate, so its success depends on individual commitment to improving science education.

Assessment: What Is Success?

Assessment has proved to be one of the most challenging tasks for undergraduate science departments. At the program directors meeting, Orville Chapman, UCLA Professor and Associate Dean for Sciences, described assessment as "the crabgrass in the academic lawn," in part because it is frequently an unfamiliar exercise. According to Dr. Chapman, assessments often overlook what *does not* work in favor of what *does* work in science education. Publicizing failures, he believes, runs contrary to the self-preservation instinct of programs.

A number of creative approaches were discussed at the meeting, but clearly there are many more questions than answers about the mechanics of assessment. One of the central questions in assessment is, How do we measure success in science education efforts? Is it strictly the training of scientists, or is it the preparation of an educated citizenry? As Dr. Steven Zottoli of Williams College expressed it, "Do you want M.D.'s and Ph.D.'s or more scientifically literate lawyers as well?" Sheila Tobias talked about the challenge of developing science programs that attract new students without sacrificing scientific rigor. Can science education programs be designed to do both?

The University of California–San Diego included an assessment component in its HHMI program from the start. Drs. Sawrey and Wienhausen held this to be vital to an effective evaluation. Their experience has indicated that front-end planning helps ensure the collection of appropriate data during the course of the program. Moreover, an external evaluation helps ensure credibility. UCSD has gained national attention for its evaluation efforts in the area of educational technology, and Dr. Sawrey is leading a systematic assessment of multimedia curriculum materials in chemistry courses. In addition, an HHMI-supported laboratory course is yielding important information about what kinds of presentations are effective in reaching students.

Another important but difficult issue, identified by Dr. Martha Crunkleton, Vice President for Academic Affairs and Dean of the Faculty at Bates College, is the need to distinguish between effects of the program and outside influences that may be causing changes. For example, changes in undergraduate science programs at Bates did increase the number of science enrollments and majors, but they coincided with national trends along similar lines. While the outcome is the same, it is crucial to determine the source of improvements for use in future program planning.

One additional assessment issue identified at the meeting included the need to move beyond the traditional notion of productivity and related quantitative measures toward more qualitative indicators. We can count the number of scientists, but as Dr. Susan Henry of Carnegie Mellon University noted, "We need better ways to follow our students' progress for several years and solicit feedback from them at regular intervals to determine the impact—not just of one class, but the entire curriculum—on the overall level of problem-solving skills."

Beyond this, educators must grapple with the notion of measuring scientific literacy among nonscientists. They must cope with the need to learn from failures as well as successes. And they must deal with questions about how to fund assessment, which can be expensive when outside experts are brought in to do a comprehensive evaluation.

Assessment is a central concern not only for improving science education, but also for securing institutional support that will help ensure a stable future for many of the undergraduate outreach programs. As in the areas of educational technology and precollege outreach, the HHMI undergraduate program will be looking more closely at different approaches to assessment with a view to enhancing program efforts. This initiative will include exploring

"We need better ways to follow our students' progress for several years and solicit feedback from them at regular intervals to determine the impact—not just of one class, but the entire curriculum—on the overall level of problem-solving skills."

—Susan Henry

"*We live in a dynamic, three-dimensional world that cannot be sufficiently well represented through the confines of a textbook, scribbling on a blackboard, or transparencies on an overhead projector.*"
—Kent R. Wilson

"*Rather than improving productivity through mass production . . . the higher education of the future should embrace new information technologies that significantly improve the quality of learning.*"
—Steven Sliwa

the extent to which grantee institutions are conducting long-term tracking and evaluation and providing a forum for people in similar situations to share ideas and experiences.

The Future of Science Education

The single most important objective in undergraduate science education is, of course, to reach individual students. This is true whether the issue is incorporating educational technology and computer-based instruction in an introductory science course, or involving young women and underrepresented minorities in science, or assessing the effects of science education programs. While reaching individual students is an obvious goal, it is not necessarily easy to achieve, since students have different educational needs and different learning styles.

In most cases undergraduate science education must serve two types of students: those who have chosen science as a career, and those pursuing other careers who want to be "scientifically literate." The latter student can be characterized as understanding the basic principles of science. This dual purpose has enormous implications for every aspect of science education, including revising curricula, developing instructional software, and designing outreach programs for precollege students and teachers. The old drill-and-practice approach in education—"drill and kill"—is especially inappropriate for undergraduate nonscience majors because it does not show science as a whole.

"We live in a dynamic, three-dimensional world that cannot be sufficiently well represented through the confines of a textbook, scribbling on a blackboard, or transparencies on an overhead projector," observed UCSD chemistry professor Kent R. Wilson in describing his development of multimedia curriculum materials for a physical chemistry course. "Something new was needed to display the chemical world in all of its glory and to improve both the understanding and the retention of chemistry by the students."[1]

Technology inspires great hope for the future of science education. However, the increased interest in educational technology raises special concerns about its potential to make education less arduous but not necessarily more effective. Steven Sliwa, President of Embry-Riddle Aeronautical University, evoked industry's distinction between mass production and mass customization and called on educators to make the same distinction in their uses of technology. The mass production model emphasizes economic efficiency and standard outputs, while mass customization means offering options and choices to accommodate consumers' individual preferences. In the case of students, this means offering options to accommodate individual learning styles.

Educational technology has the power to individualize instruction, but it must be used thoughtfully. It should not supplant contact between faculty and student, or collaboration with student peers. "Rather than improving productivity through mass production," Sliwa writes, "the higher education of the future should embrace new information technologies that significantly improve the quality of learning."[5] This advice applies not only to technology, but to all innovations in science education.

When science educators talk about the future of their field, there is a sense that the stakes are very high. As Alfred North Whitehead once observed, "In the conditions of modern life the rule is absolute; [a country] that does not value trained intelligence is doomed."[6] But there is also a strong possibility that science education can adapt well to the conditions presented by modern life, through advances in educational technology, curriculum development, program assessment, and other tools available to reshape science programs. Improving these tools and using them effectively are rewarding challenges to those involved in the science education enterprise. HHMI is pleased to assist in these endeavors—and to present the proceedings of the 1994 undergraduate program directors meeting.

"In the conditions of modern life the rule is absolute; [a country] that does not value trained intelligence is doomed."
—Alfred North Whitehead

References

1. Guskin, Alan E. "Restructuring the Role of Faculty." *Change*:23, Sept./Oct. 1994.
2. The Pew Higher Education Roundtable. *Policy Perspectives* 5:3A, April 1994.
3. Winston, Gordon C., "The Decline in Undergraduate Teaching: Moral Failure or Market Pressure?" *Change*:11, Sept./Oct. 1994.
4. Illman, Deborah L. "Multimedia Tools Gain Favor For Chemistry Presentations." *Chemical and Engineering News*:31, May 9, 1994.
5. Sliwa, Steven. "Re-Engineering the Learning Process with Information Technology." *Academe*:12, Nov.–Dec. 1994.
6. Whitehead, Alfred North. Quoted by Bruce M. Alberts in "Science as Science Educators." *Issues in Science and Technology*: 32, Spring 1994.

Undergraduate Program Overview

Since 1988 the Institute's Undergraduate Biological Sciences Education Program has awarded $290 million in grant support to 213 colleges and universities for undergraduate science education (Figure 1). The goal of this program is to support efforts to strengthen the national quality of college-level education in the biological sciences and other scientific disciplines as they relate to biology. Another important objective is to support outstanding programs that seek to attract and retain students in scientific fields, including women and members of minority groups underrepresented in the sciences.

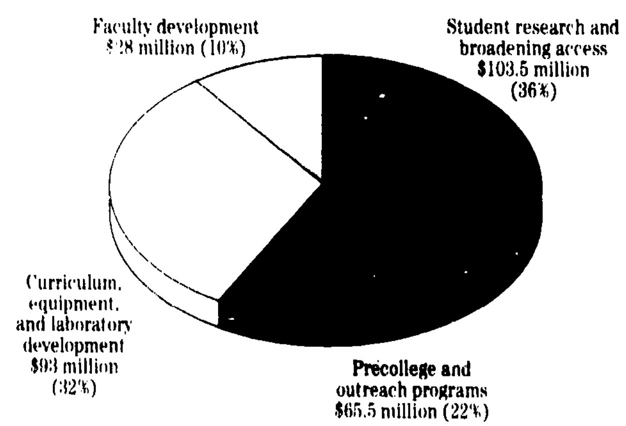
Institutions have been invited to participate in the undergraduate competitions on the basis of their recent records of having graduated students who went on to medical school or to earn Ph.D.'s in biology, chemistry, physics, or mathematics. Data for these assessments were provided by the Association of American Medical Colleges, the National Research Council of the National Academy of Sciences, and the U.S. Department of Education (Figure 2).

To identify institutions as eligible to be included in each assessment, the Institute has referred to the 1987 classification of higher-education institutions by the Carnegie Foundation for the Advancement of Teaching. This classification is based on such factors as the level of degree offered, nature of the educational mission, degree of specialization in particular fields, and amount of annual federal support for research and development. The Institute has also taken into account institutions' records of preparing students from minority groups underrepresented in the sciences to pursue scientific careers.

Proposals are reviewed by an external panel of scientists and educators. Their evaluations, in turn, are reviewed by an internal Institute committee that makes recommendations to the Institute's Trustees, who authorize funding.

Figure 1

Awards to 213 Colleges and Universities ($290 million) by Program Component, 1988–1994 Competitions



Grants Competitions and Awards

Phase I, 1988–1992. In the first phase of the undergraduate program, 1988–1992, HHMI provided a total of $175.4 million to 181 institutions for grants to support undergraduate science education. The institutions were encouraged to develop programs responding to their particular needs and strengths. Accordingly, the undergraduate program supports a range of activities in numerous scientific disciplines at participating institutions. These activities include student, faculty, and curriculum development and precollege and outreach programs.

Figure 2

Assessment Criteria

In 1989–1994, institutions were assessed for participation in the Undergraduate Biological Sciences Education Program on the basis of the percentage (calculated with data on total baccalaureate degree production collected by the U.S. Department of Education) and absolute number of graduates from each institution who have:

Matriculated in medical schools
Data Source: Association of American Medical Colleges.

Earned doctorates in biology
Data Source: National Research Council of the National Academy of Sciences.

Earned doctorates in chemistry, physics, or mathematics
Data Source: National Research Council of the National Academy of Sciences.

Note: Assessment for the 1989–1990 competition was based on data for the periods 1978–1986 (for medical school matriculation) and 1977–1986 (for doctorates earned in biology, chemistry, physics, or mathematics). Assessments for the 1991, 1992, 1993, and 1994 competitions were based on data for the period 1979–1988 (for medical school matriculation and doctorates earned in biology, chemistry, physics, or mathematics).

The first phase of the undergraduate program began in 1988 with the initial grants competition in which HHMI invited 81 private liberal arts colleges and 18 public and private historically black institutions to apply for five-year grants to bolster their science programs. Following review of the 99 proposals by external and internal panels of scientists and educators, 44 institutions, including 34 private four-year colleges and 10 public and private historically black institutions, were awarded a total of $30.4 million in HHMI grant support. (For further information see Howard Hughes Medical Institute, *Grant Programs Policies and Awards, 1988–1989.*)

In 1989, 101 research and doctorate-granting universities were invited to submit proposals to enhance undergraduate education in biology and related fields. Following review of the proposals, HHMI provided grants totaling $61 million to 51 universities. These awards were paid by HHMI over a two-year period. (See Howard Hughes Medical Institute, *Grants for Science Education, 1989–1990.*)

In 1991 a total of 98 public and private comprehensive and liberal arts colleges and universities, including institutions with demonstrable records of educating underrepresented minority students in the sciences, competed for undergraduate awards. A total of 44 institutions, including 10 with records of educating underrepresented minority students, received grant support totaling $31.5 million for a range of program activities. (See Howard Hughes Medical Institute, *Grants for Science Education, 1990–1991.*)

The first program phase was completed in 1992, when a fourth competition was held in which 98 research and doctorate-granting universities were invited to submit proposals. HHMI awarded grants totaling $52.5 million to 42 of these institutions. (See Howard Hughes Medical Institute, *Grants for Science Education, 1991–1992* and *1993 Undergraduate Program Directory, A Listing of Program Directors and Grants Awarded at 181 Colleges and Universities, 1988–1992.*)

Figure 3

Program Elements and Guidelines

1988–1992	1993–1994
■ *Student and faculty development*—supporting undergraduate research experiences, opportunities for women and minority students underrepresented in the sciences, and new faculty appointments—included as program elements	■ *Student research*—including opportunities for women and minority students underrepresented in the sciences—retained as program element
■ *Curriculum and laboratory development*—supporting new and revised courses, equipment acquisitions, and laboratory renovations—included as program elements	■ *Equipment and laboratory development*—supporting equipment acquisitions and laboratory renovations for undergraduate laboratory courses—retained as program element
■ *Precollege and outreach programs* included as program element	■ *Precollege and outreach programs* retained as program element
■ Support for equipment and laboratory renovation limited to 30 percent of total grant amount	■ No limitation on funding for equipment: funding for renovation limited to 50 percent of total grant amount
■ Five-year grant period	■ Four-year grant period

Phase II, 1993–1994. HHMI's 1993 and 1994 competitions mark a new phase in its undergraduate program (Figure 3). This second phase was developed, in part, on the basis of findings from HHMI's ongoing assessments of the undergraduate program. An important source of information for undergraduate program development is the annual meeting of program directors. One finding, discussed extensively by the program directors, has been the importance of undergraduate research as a means of attracting and retaining students, including women and members of minority groups underrepresented in science.

The 1992 program directors meeting focused on undergraduate research and the increased need for enhanced laboratory instruction and equipment. The theme of the 1993 meeting was institutional strategies for enhancing undergraduate science teaching and learning.

At these meetings the program directors noted the important role that colleges and universities can play in enriching precollege science education. A number of

Figure 4

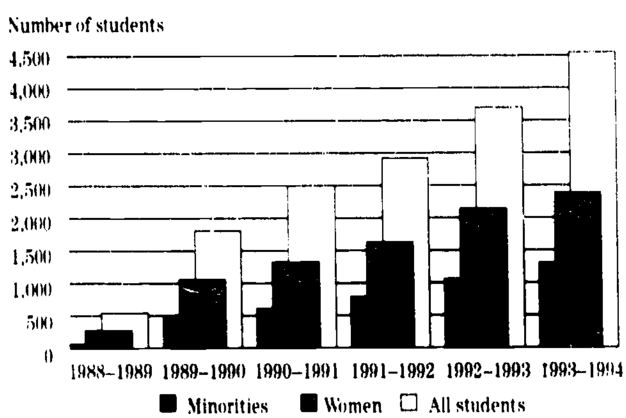
Number of Grantee Institutions by Carnegie Foundation Classification, 1988–1994

Carnegie Classification	Number* Phase I 1988–1992	Phase II 1993–1994
Research Universities I	55	38
Research Universities II	21	11
Doctorate-Granting Universities I	11	8
Doctorate-Granting Universities II	5	5
Comprehensive Universities and Colleges I	20	18
Comprehensive Universities and Colleges II	3	2
Liberal Arts Colleges I	56	22
Liberal Arts Colleges II	8	5
Schools of Engineering and Technology	2	--
Totals	181	109

**Includes all institutions receiving awards in phase I and II competitions.*

Figure 5

Student Participation in Undergraduate Research: Women and Underrepresented Minorities, 1988–1994



	Number	Percent
All students	16,030	100
Women	8,873	55
Minorities	4,441	28

the presentations have focused on grantee-developed activities to provide laboratory and classroom training for students and teachers from elementary and secondary schools and from two- and four-year colleges.

The annual progress reports submitted by grantee colleges and universities are another important source of background for undergraduate program development. Over the six years of the program, the directors have underscored in their reports the importance of equipment acquisitions and laboratory development supported by their grants in enabling them to provide instruction in the contemporary biological sciences and other disciplines as they relate to biology. In addition, they point to the energizing effect of equipment and laboratory enhancements on undergraduate research and precollege and outreach programs. They also draw attention to a critical need for continued support to modernize the undergraduate science infrastructure. These three program areas—student research and broadening access, equipment and laboratory development, and precollege and outreach—are retained as elements in the second program phase.

In 1993 a total of 175 public and private comprehensive and liberal arts colleges and universities, including institutions with demonstrable records of educating underrepresented minority students in the sciences, competed for undergraduate awards. A total of 47 institutions, including 18 with significant presence of underrepresented minority students in the sciences, received grant support totaling $28.5 million. (See Howard Hughes Medical Institute, *Grants for Science Education, 1994*.)

The second program phase was completed in 1994, when a sixth competition was held in which 140 research and doctorate-granting universities were invited to submit proposals. HHMI grants totaling $86 million, awarded over a four-year period, are supporting 62 of these institutions. Figure 4 lists the number of undergraduate grantees for phases I and II by Carnegie Foundation classification. Some institutions received grant awards in both program phases, as reflected in the totals.

Figure 6

Undergraduate Research by Site, 1988–1994

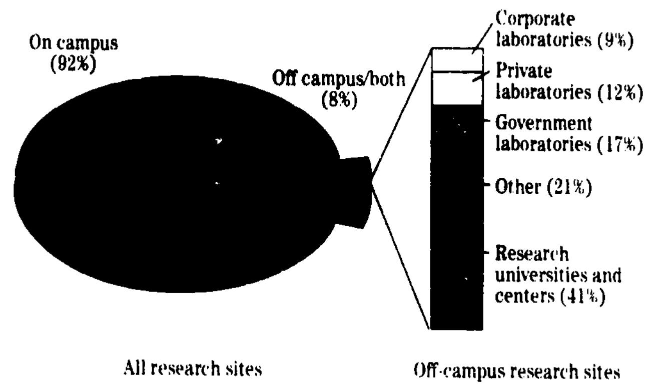
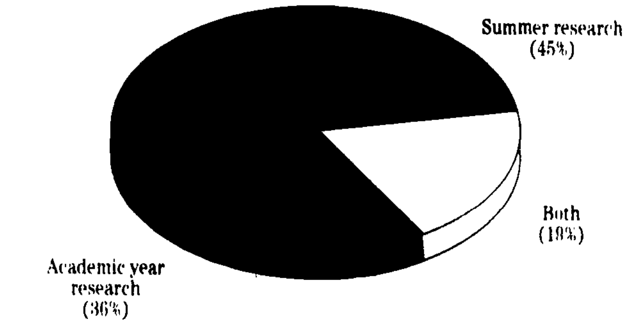


Figure 7

Undergraduate Research by Academic Period, 1988–1994



Summary of Program Activities

Student Research and Broadening Access. Of the total funding of $290 million provided in the first and second phases of the undergraduate program, approximately $103.5 million is being used at 170 institutions for programs to recruit and retain students in the sciences, especially those underrepresented in scientific fields, such as women, blacks, Hispanics, and Native Americans. The principal student activity supported under the programs is undergraduate research, providing opportunities for students, many with no prior laboratory experience, to learn scientific concepts, terminology, and techniques while assisting scientists in research projects on or off

Figure 8

New Faculty Appointments, 1988–1994

	Number	Percent
All faculty appointments	208*	100
Women	101	49
Underrepresented minorities	23	11

*Includes 160 tenure track appointments

Figure 9

New Faculty Appointments by Scientific Field, 1988–1994

Field	Number of Appointments
Cell or molecular biology	54
Biochemistry, biophysics	37
Neuroscience	28
General biology	12
Chemistry	10
Embryology, developmental biology	9
Immunology	8
Genetics	6
Ecology, environmental sciences	6
Physics	5
Physiology	5
Biometry, biostatistics, computational biology	5
Microbiology, bacteriology, virology	4
Other scientific fields	19
Total	**208**

campus. At a number of institutions, these research experiences have been enhanced when preceded by training activities and followed by opportunities for students to present their research and publish significant findings.

Since its inception in 1988, the undergraduate program has supported nearly 16,000 undergraduates conducting research. Of this total, 55 percent are women and 27 percent are students from minority groups underrepresented in scientific fields (Figure 5). Most of the students conducted research with faculty members at their own institutions, and a limited number worked off campus in government laboratories, at other universities or colleges, or in private corporations (Figure 6). Forty-five percent of these research experiences took place during summer, 36 percent during the academic year, and some spanned both periods (Figure 7).

Grantee institutions have reported the significance of undergraduate research opportunities in attracting student interest in the sciences and helping to retain that interest through the college years and beyond. According to a number of participating students, HHMI-supported research experiences have been major factors in gaining acceptance into outstanding graduate and medical programs and receiving national fellowships. For example, several undergraduates receiving research support through this program have gone on to receive fellowships under HHMI's highly competitive predoctoral fellowship program.

Faculty Development in the Sciences. In the initial program phase, a total of $28 million has been used by 98 awardee institutions for science faculty development, including the appointment of new faculty members, programs to engage research faculty in undergraduate teaching, and other activities. Since 1988, HHMI funds have enabled 88 colleges and universities to appoint 208 faculty members in a range of scientific disciplines. These HHMI-supported appointments include 101 women (49 percent) and 23 faculty members from minority groups underrepresented in scientific areas (11 percent) (Figure 8).

These appointments are providing departments with opportunities to develop new courses in important areas of modern science and to update and expand existing curricula.

The scientific disciplines in which HHMI-supported faculty have been appointed include cell and molecular biology, biochemistry/biophysics, and neuroscience (Figure 9). In several cases the new appointments have enabled institutions to bridge science departments, such as biology and chemistry, in the development of interdisciplinary programs. The new faculty members have begun to distinguish themselves at their colleges and universities, which are reporting important contributions in teaching, research, and institutional service.

HHMI provides funds for activities that enrich the current faculty scientists' knowledge of their fields and enhance their ability to convey new knowledge to students. Science faculty members received support to participate in on- and off-campus workshops, seminars, and training programs in the sciences. In addition, a number of faculty received HHMI support to attend professional meetings.

Figure 10

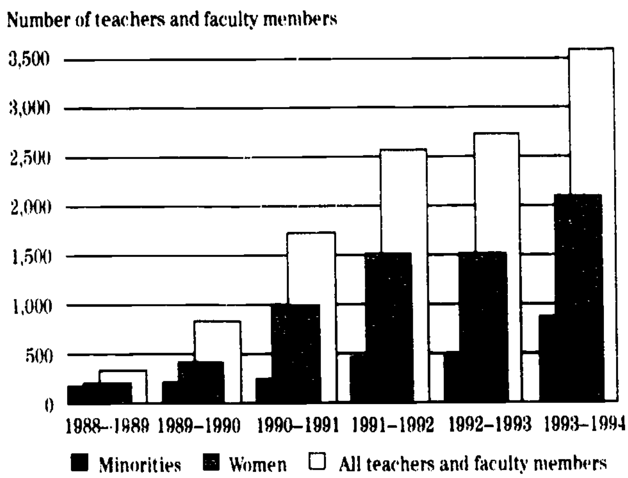
Selected New Courses by Scientific Field, 1988–1994

Area	Number of Courses
General biology	399
Chemistry	319
Molecular biology	292
Biochemistry	285
Cell biology	253
Neuroscience	201
Physiology	166
Genetics	162
Laboratory techniques	155
Topics in biological sciences	142
Physics	140

Curriculum and Laboratory Development and Equipment. A total of $93 million has been directed to the development of science curricula and laboratories, enabling nearly all 213 grantee institutions to enhance the quality of instruction in the biological sciences and other disciplines as they relate to biology (Figure 10). HHMI grant support in this area is principally directed to the acquisition of modern scientific instrumentation and laboratory renovation. The program also supports the development of new experiments for use in courses, laboratory manuals, and other instructional materials.

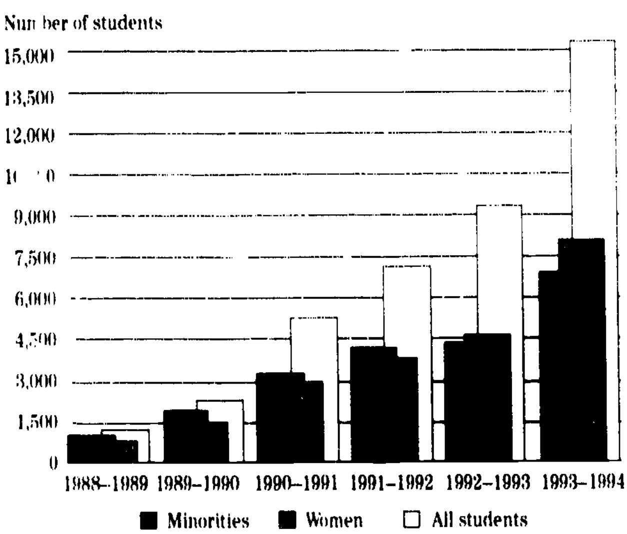
Figure 11

Teachers and Students in Outreach Programs, 1988–1994



Teachers and Faculty Members

	Number	Percent
All teachers	11,837	100
Women	6,746	57
Minorities	2,422	20



Students

	Number	Percent
All students	40,563	100
Women	21,577	53
Minorities	21,753	54

Since 1988 HHMI has supported the development of approximately 3,300 courses covering a wide range of scientific disciplines such as genetics, molecular and cell biology, and neuroscience. Approximately 30 fields of biology and other disciplines are represented. Numerous institutions are using their awards to relate biology teaching to chemistry, physics, mathematics, and computer science. In such cases, biological examples are integrated into laboratory courses in the physical sciences and other areas.

Another important objective of HHMI's support of curriculum and laboratory development is the enhancement of opportunities for hands-on laboratory research in undergraduate science courses. Grantee colleges and universities are developing teaching laboratories at the introductory through upper-division levels, providing undergraduates with research experiences that may be continued in faculty laboratories. Institutions report that for many students these research experiences are stimulating interest in science majors and careers.

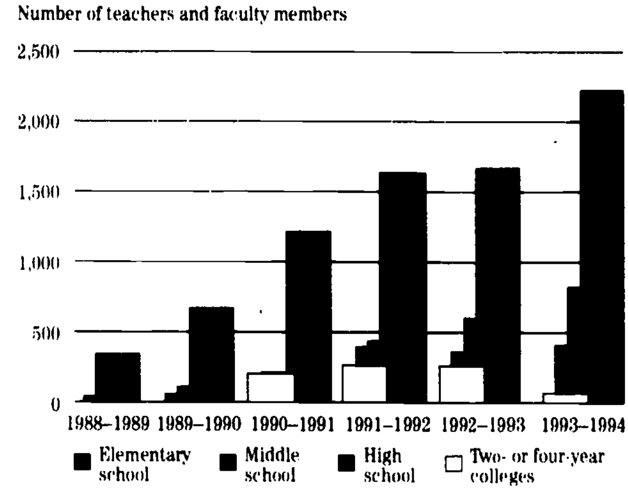
Precollege and Outreach Programs. HHMI has awarded $65.5 million to 186 grantee colleges and universities to expand existing linkages or to develop new ones with precollege and other institutions. The objective of these initiatives is to enhance the quality of science programs at these institutions. They are also intended to attract and retain students in the sciences, particularly women and students from underrepresented minority groups.

Programs include summer and academic-year laboratory experiences for teachers and students, summer science camps, equipment loans, curriculum development, and classroom training for students in biology and chemistry, physics, mathematics, and other areas as they relate to the biological sciences. Approximately 11,800 teachers, of whom 57 percent are women and 20 percent are minority group members, have participated in HHMI-supported outreach programs since 1988 (Figure 11). In addition, over 40,000 students, including 53 percent women students and 54 percent minority students, have benefited from these outreach initiatives.

Teachers from elementary, middle, and high schools, faculty members from two- and four-year colleges, and students from these institutions have been involved in HHMI-supported outreach programs. Among the participating teachers, approximately 65 percent have been from high schools, with elementary and middle school teachers and two- and four-year faculty also significantly represented (Figure 12). Among the students, 62 percent have been from high schools. In addition,

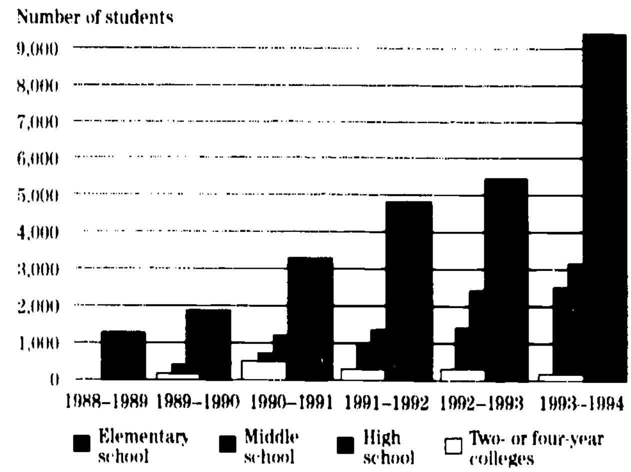
Figure 12

Teachers and Students in Outreach Programs by Grade Level, 1988–1994



Teachers and Faculty Members

	Number	Percent
All teachers	11,837	100
Elementary school	1,747	15
Middle school	1,629	14
High school	7,678	64
Two- or four-year colleges	783	7



Students

	Number	Percent
All students	37,385	100
Elementary school	8,296	22
Middle school	5,618	15
High school	23,036	62
Two- or four-year colleges	435	1

students from other educational levels have participated.

Colleges and universities have reported on the laboratory activities of precollege students participating in HHMI-supported outreach programs. A number of these students have received recognition for their research through programs such as the Westinghouse Science Talent Search and in local, regional, and national science fairs. Many have also been accepted into leading undergraduate science programs. In addition, a number of teachers from elementary and secondary schools have noted improvements in their science teaching as a result of their participation in HHMI programs.

The Two Cultures Revisited: Science and Mathematics as the New Liberal Arts

Sheila Tobias

I want to start this talk with a question of profound importance to ourselves and to our nation, namely: Why is it so difficult to convince students and educators alike that mathematics and science are "liberal arts"? And in the course of my talk, I want to try to answer that question and to challenge you at your various institutions to make them so.

One reason that mathematics and science are *not* perceived to be liberal arts is that mathematics and science have become elitist endeavors, meant only for a self-selected, dedicated few who would use them in pursuit of their careers, or for a smaller, even more elite number who have the potential for advancing these disciplines. Another reason is that the *non*-math/science professoriate know too little of the substance or grandeur of mathematics and science to include them in the history of western thought.

As a result, math and science are presented at most of our colleges and universities as a set of skills to be mastered, separate from and indeed irrelevant to the arts and the humanities.

With the curriculum cut up in this particular way, it's not surprising that most undergraduates—both those who pursue math, science, and engineering and those who take the one or two required courses in these fields and then quickly flee—leave college convinced that math and science are not historical somehow, nor philosophical, nor even of human design and human invention. It is facts or the techniques that are emphasized, not how people came to know certain things to be true, or what caused people of a given generation to accept one model of natural reality and not another.

When we teach the works of Aristotle, Machiavelli, and Rousseau—on the other side of the campus—we know, and in time our students know too, that those particular ideas were supplanted by later theories, but we teach them just the same, because these philosophies represented *important steps* in the development of western thought. By not being treated in the same way, mathematics and science are made to seem fixed and unchanging and not part of any tradition. Not until much later, and sometimes not ever, do students realize that mathematics and science are more than "the practice of," and that, in fact, politics and economics, the dominant religions and the heresies they gave rise to, trade routes, and even war contributed to the development of scientific and mathematical thought. For while they get introductory overviews in the liberal arts, they study mathematics and science courses in a vertical structure of ever-increasing competencies.

In short, professors of math and science don't show themselves to be competing for standing in the "liberal arts." To the contrary, the way mathematics and science are generally presented, they are in no way connected to anything else but themselves.

The fault, as I will say often in this talk, lies quite as much with the historians, philosophers, and specialists in "culture" as it does with the mathematics and science faculty.

The reason students have to discover *for themselves* that mathematics and science have both a history and a culture is this: Their science and mathematics courses leave out history; their history and philosophy courses leave out science and mathematics. As educators, we dare not countenance such a compartmentalization, for if we do, we replicate a larger problem in society as a whole, namely the problem of two mutually exclusive intellectual "cultures" that, after the "distribution requirements" are out of the way, have neither the inclination nor the means to converse. Yet it is that conversation—as I find again and again in my work—that is most critical for our faculty, our college students, and our nation to pursue.

The Two Cultures

We can trace the origin of the phrase "the two cultures" to the British scientist C.P. Snow, who introduced it to the world in his celebrated Rede Lecture in 1959. Snow's observation—from years of interviewing British scientists and members of his nation's literary elite—was that while ignorance of major literary texts like Shakespeare's plays, for example, would not be tolerated among self-styled intellectuals, scientific illiteracy was often worn like a trophy. His example, made famous in his book *The Two Cultures*, is that writers and other nonscience elites could not explain—when he asked them specifically to do so—the significance of the second law of thermodynamics. Most of them, in fact, didn't know what he was talking about when he mentioned the Second Law.

Snow's criticism was not aimed solely at literary elites. In his interviews with wide-ranging groups of British scientists, Snow found comparable insularity: scientists do not read widely for aesthetic or inspirational pleasure; novels, history, poetry, and plays matter very little to them, and for the humanities, they have nearly universal disdain. Snow was not just throwing brickbats. As a professional physicist and sometime novelist he was concerned that the lack of a common language between the two cultures could lead to hostility.

Snow was aware that the scientific culture is no monolith and that many biologists do not have anything but a hazy understanding of modern physics (and the reverse), but he believed that, compensating for this, there are among scientist-intellectuals "common attitudes, common standards and patterns of behavior, common approaches and common assumptions,"[1] commonalities that our students—all of them, not just our science majors—should know about and appreciate.

For one thing, as Snow expressed it, "[scientists] have the future [not the past] in their bones."[2] They are less impressed with things (or ideas) that once held sway than with emerging truth. For another, they are skeptical of ideas that are advanced only on the backs of arguments and not rooted in empirical fact or experiment. Third, they share a similar experience of being "excluded," even looked down upon, by the literati.[3] For while they are clear thinkers, they don't talk in terms of recent authors or literary metaphors. As a result, people who are not like them think that scientists are not considered "intellectuals" at all by the other group.

Snow himself bridged the two cultures. He was a scientist and a writer as well. As part of his contribution to manpower planning for Britain during World War II, he and his colleagues had interviewed nearly 25 percent of his nation's scientists. He found them to be, as far as literary culture was concerned, impoverished. He also knew his literary colleagues and described them as impoverished as well: "They ...like to pretend that the traditional culture is the whole of 'culture,' as though... the scientific edifice of the physical world was not, in its intellectual depth, complexity and articulation, the most beautiful and wonderful collective work of the mind of man." So meager is their education in science, according to Snow, that even if they wanted to know the scientific edifice, they couldn't, because they knew too little of its basics. "As with the tone-deaf," he wrote, "they don't know what they miss."[4]

Keynote speaker Ms. Sheila Tobias challenges the "two cultures" of science and liberal arts education to join forces on behalf of science literacy.

The Industrial Revolution

What was the source of mutual disdain between the two cultures?

Snow, of course (as we all do) laid much of the blame on education: too early specialization in the English system and too little commitment to a rigorous general education in science, even in the American. But more provocatively, he traced the beginning of the disparity (and mutual disparagement) between the two cultures to the industrial revolution.

The industrial revolution, he pointed out, did not engage English or American intellectuals. All the new thinking involved, he said, was done by "cranks and clever workmen."[9] While the Germans educated their young in the applied sciences, the English and Americans excluded engineering from their elite colleges for a much longer time. As a result, those who comprised the intellectual circles in our two countries were not able to comprehend what was happening as farming was replaced by mining and manufacturing.

Even though subjects for poetry and fictions were there to be mined, only Lewis and Dreiser in this country, Dickens, Ibsen, and Zola, in Europe, took their "imaginative sympathy" to the "hideous back-streets, the smoking chimneys," and the technologies of the industrial revolution.[10] Most of the writers elected to "contract out," as Snow put it, denying or denigrating the industrial revolution.

Snow was not just concerned about the lack of understanding between the two cultures, but about the political consequences of this polarization as well. If decision-makers did not know enough science, they would not be able to make sense of the advice scientists provided (not even be able to judge which scientists' advice to take)—a problem that has come home to roost in this country as more and more policy determinations involve technology and science.

Still, for all his critical dissection of the gap between the two cultures, the problem as Snow saw it in 1959 was "regrettable" but not yet really dangerous. The situation in Snow's day had not yet reached disastrous proportions. The "moderns" (today, we would add the postmoderns), like their predecessors the "romantics," made of their scientific illiteracy a kind of fetish. But the great mass of the people appeared to Snow at least to retain a confidence in science, even if they were ignorant of it.[11] The point is, at the time of Snow's commentary, *anti-science* did not yet abound.

The Anti-Science Movement

Over 35 years have passed since Snow's Rede Lecture. In that period, the semiconducter revolution has taken its rightful place as a "second industrial revolution"; the structure of the DNA molecule, only just cracked by Crick and Watson in the period in which Snow was writing, is now the basis of biology. In that same period, American education has gone through at least two cycles of reform, involving the New Math, hands-on science, and phonics in the elementary grades, and general and interdisciplinary education, writing-across-the-curriculum, and physics-for-poets in college.

Despite all this, science illiteracy appears to have entered a second, more pernicious stage, fueling a widespread opposition to science—in opposition, to quote physicist and science historian Gerald Holton, that "threatens to topple the Enlightenment-based tradition on which scientific discourse and democratic politics are based."[12]

The conference at which Gerald Holton made these remarks was not about science literacy per se; not even about the Two Cultures; but, as I read it, something of an update on the issue Snow had raised in 1959. It was the first post–Cold War gathering of Soviet and American scientists, called to help the Soviets deal with a "Glasnost-released" flowering of publications promoting "other ways of knowing" from mystics, clairvoyants, astrologers, and the like.

The title of the conference is revealing. It was called "Anti-Science, Anti-Technology Movements in the U.S. and USSR." Holton's keynote address set the tone. The issues embedded in "anti-science/anti-technology," said Holton, are not just inadequate supplies of future scientists or erroneous policy decisions made by science-ignorant elites, but constitute a threat to a secular rationalism on which the modern tolerant society has been based.

For Holton, more than for Snow, there is a real *peril* for the two nations in science illiteracy, for, as he said, "History has shown repeatedly that a disaffection with science and its view of the world can turn into far more sinister movements." Scientists, said Holton, like Snow before him, are partly to blame. It is their elitist indifference to what common people learn in school. As a result, more and more people—even college-educated adults—are turning toward a "powerful countervision" of the world that involves the "delegitimization" of conventional science and the promotion of an alternate "pseudoscience" in its place.

Toward a General Education

I ask you today to consider what faculty, graduates, and students are to make of these two analyses and, more importantly, how these might inform our deliberations on the content and methods of any general education curriculum we might envision for the liberal arts.

First, we should acknowledge that nonscience students (partly because of math avoidance, partly because of the way science is presented) will resist a science (or mathematics) component of a general education curriculum more than they will any other subject matter until and unless it is made to bear some relevance to their lives and work. Second, we need to acknowledge that in their disdain for (or fear of) science and mathematics, our students are very often reflecting views that they see around them, not just at home or in popular culture, but in the way the disciplines are divided on their own campus. Third, it will require an enormous and painful ideological shift on the part of science (and mathematics) faculty when we ask them to introduce liberal arts students to their disciplines *in ways they are unused to.*

In any discussion of a future liberal arts curriculum these should be our goals:

■ The "liberal arts" should not obliterate the distinctions between disciplines, but should make students more knowledgeable about them. Upon graduating from general education courses, students should be aware that there are very many ways of attaining truth, and be master of more than one.

■ The faculty should itself become at least as broadly educated as we want our students to be. This may mean involving faculty in learning new subjects and new ways of knowing—a task that is difficult for adults who have not crossed a disc'plinary boundary in years.

■ Faculty not involved in planning or teaching general education science and math courses should be familiar enough with their content and pedagogy to make substantial reference to them and to recommend them (certainly not to denigrate them as "watered down" subject matter) in other courses that they teach.

■ In short, general education has to be an educational experience not just for college students but for college faculty as well.

How does one go about generally educating the entire community? I want to recommend, as one possibility, a model of cross-disciplinary exploration that I have used in researching the question "What makes science (and mathematics) hard?" but which could just as well serve as a model for faculty participation in general education.

Since 1984 I have been investigating the resistance of otherwise intelligent students to science, and the elitism and insider/outsider notions that instructors in science bring to their teaching. To examine these issues, I have conducted a series of experiments where nonscience faculty acted as "surrogate learners" in introductory chemistry, physics, and calculus courses (and once, in a reverse experiment, where science and engineering faculty acted as "surrogate learners" in the serious study of poetry).

In these experiments, I found that because they were newcomers to these fields, these outside faculty were able to *notice* the kind of packaging (delivery systems, one might say) that accompany lessons, labs, demonstrations, and even examinations, in science, and to articulate problems that ordinary undergraduates might not be able to sort out from the new material itself.[11] There was in science, for example, too little overview, too little discussion and debate, too much emphasis on problem-solving skills—uninspiring homework assignments and examinations and altogether not nearly the intellectual adventure they wanted from science.[12] None of the faculty engaged in my experiments would have described himself or herself as "anti-science." But the courses, as they experienced them, did not prepare them to defend science or the scientific world view in the face of anti-science or science ignorance.

The challenge of being a novice in someone else's field works both ways. When I placed 14 science and engineering faculty in a seminar on Chaucer and Wordsworth in what was for them a new literary criticism frame of reference, the learners found themselves butting against similar walls, some self-imposed, some the result of certain closed-ended traditions in humanistic teaching. And these walls got in the way of their understanding of the material being presented and caused them difficulty in understanding poetry and appreciating the power of the analytical methods employed to make sense of poetry.[13]

Scientists and engineers, for example, were uncomfortable reading something they did not understand and having to find various levels of meaning, even when they knew this was the whole point of the exercise. Claims that "the poet intended..." or that the "poet's audience would have recognized..." left them unconvinced. For the scientists and engineers, the problem was partly presentation—"too many words" and not enough visual hints or displays—partly a course sequence they characterized as "meander and grope" instead of a step-by-step building toward understanding. As for their written assignments, science and engineering faculty did not know how to deal with questions that rewarded clever playfulness rather than rigorous analysis, and minded that they were marked "wrong" if their papers were too short.

Peer perspectives encounters, as I call them, could provide a sort of dress rehearsal for general education. Here's why:

■ Because they are not barred by anything other than the disciplinary barrier—they are not unintelligent, not unfocused, not unmotivated—nonspecialists could lay out for disciplinary specialists precisely what keeps the two cultures apart.

- Problems and resistances that students might have could be aired and addressed before the courses are taken to them.
- Faculty in certain fields who might otherwise "contract out" of general education because it does not reflect their priorities, could be more productively engaged.

The alternative to this dress rehearsal for general education is more rather than less division between the two cultures. We want to show students that the two cultures connect and overlap, not that they are estranged.

Conclusion

Not everyone needs to understand science as a scientist does; not everyone can. But the large majority must understand much more than they do now. To accomplish that, in my view, our scientists and mathematicians must learn how to teach students who are not just younger versions of themselves. It is essential for them to realize that they are dealing not just with subject matter but with human, malleable minds.

The way to make mathematics and science part of the liberal arts, then, is not to think of our teaching as piling one slab of new knowledge upon another. But rather to think of it as increasing the stickiness and the surface area of the student's mind itself so that, with every passing year, there is more sticky stuff in place, more yearning to know, and more capacity to learn.

One way to assess a general education or liberal arts curriculum, then—and this is one that meets my "stickiness" test (some call it my flypaper theory of education)—is to find out not just what students know a he end of four years, but what they want to know and what they intend to go on learning for life. And this learning for life must include mathematics and science understood as liberal arts until, for each individual college student, the two cultures cease to be two, but are understood to be—as I understand them—a composite gift of past generations to enrich and to guide our personal and professional lives.

References

1 C.P. Snow, *The Two Cultures and a Second Look*, Cambridge, England: Cambridge University Press, 1964

2 Snow, op.cit., pp. 14, 72

3 Snow, op.cit., p. 12

4 Snow, op.cit., p. 4

5 Snow, op. cit., p. 10

6 Snow, op.cit., p.4

7 Snow, op. cit., p. 14

5 Ibid.

9 Snow, op. cit., p. 24

10 Snow, op. cit., p. 25

11 Snow, op. cit., p. 93

12 Gerald Holton, "How to Think About the 'Anti-science' Phenomenon," a presentation to the joint US-USSR conference on "Anti-Science and Anti-Technology Movement in the US and USSR," held May 2-3, 1991, at MIT, and printed in *Public Understanding of Science* 1, 103-128, 1992. I am grateful to Richard Hake of the physics department at Indiana University for bringing Holton's article to my attention.

13 Holton, op. cit., p. 185.

14 Sheila Tobias, "Peer Perspectives on Teaching," *Change* magazine, Spring, 1986; See also (with Richard Hake) "Professors as Physics Students: What Can They Teach Us?" *American Journal of Physics*, 56 (9), September 1988, p. 77.

15 Sheila Tobias, *They're Not Dumb, They're Different: Stalking the Second Tier*: Research Corporation, 1990.

16 Sheila Tobias and Lynne Abel, "Poetry for Physicists," *American Journal of Physics*, 59 (9), September 1990, p. 816. See also "Peer Perspectives on the Teaching of Poetry," by the same authors in the American Council of Learned Societies *Newsletter*, Vol. 1, No. 4, Autumn 1988.

Biographical Sketch ■ Sheila Tobias

Sheila Tobias is a lecturer, author, and consultant on undergraduate science education. Currently she is a consultant to The Research Corporation, Tucson, Arizona, and consultant and program evaluator to the H. Dudley Wright Foundation for the Advancement of Science, Geneva, Switzerland. She is a Visiting Professor at the University of California–San Diego in the Department of Political Science, where she teaches courses relating to gender and politics and to feminist theory. Ms. Tobias is a Visiting Scholar in the Department of Political Science, University of Arizona. She is also involved in several NSF-funded projects: microscale laboratory teaching in chemistry, minority science education, and teacher preparation in science.

Ms. Tobias received an A.B. in history and literature from Harvard University/Radcliffe College, magna cum laude, and Phi Beta Kappa (1957); an M.A. in European history from Columbia University, where she was a Woodrow Wilson Fellow and a President's Fellow (1961); and an M.Phil. from Columbia University (1974).

Her early work experience includes eight years as a press and television journalist and administrative positions at Cornell University (1967–1970) and Wesleyan University (1970–1978). From 1978 to 1981 she directed math anxiety projects with the Institute for the Study of Anxiety in Learning of the Washington School of Psychiatry, Washington, D.C.

Her current research interests include a long-standing study involving nonscience faculty in artificial learning situations to see what makes science hard to comprehend; mathematics avoidance and anxiety; and assessment and evaluation of students, curricula, and programs. Her commitment to the field of women's studies involving science and mathematics has spanned twenty-five years.

Ms. Tobias has written and coauthored several books in these areas. Among her most recent publications are *Breaking the Science Barrier*, with Carl Tomizuka (The College Board); *They're Not Dumb, They're Different: Stalking the Second Tier*, and *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't* (Research Corporation); and *Overcoming Math Anxiety* (W. W. Norton). To be published soon are *In-Class Examinations: New Theory, New Practice*, with Jacqueline Raphael (California State University Press) and *Science as a Career: Perceptions and Realities* (Research Corporation). In addition, she has published articles in many journals.

Strategies to Involve Faculty Members in Precollege and Outreach Programs

Xavier University of Louisiana ■ Deidre Labat, Ph.D., Jacqueline Hunter, Ph.D., JW Carmichael, Ph.D.

Xavier University of Louisiana has developed an educational pathway program beginning as early as 8th grade to nurture promising African American students through high school and the university and into a graduate or professional school in the biomedical sciences. The panel for the plenary presentation included three Xavier faculty members instrumental in the pathway programs. Dr. Jacqueline Hunter presented an overview of the program and the university. Dr. JW Carmichael described successful strategies to involve faculty in the program. Dr. Deidre Labat moderated the discussion. Participants wanted to know more about professional recognition for faculty involvement and about the administrative infrastructure to support that involvement. They also asked how well high school students in the program do and how more science students might be persuaded to see graduate school as an alternative to medical school.

Presentations

Xavier University is a small, historically black liberal arts college located in the center of New Orleans, Dr. Hunter said. Since 1986 the student population has grown 75 percent, and in 1994, 52 percent of the university's 3,282 students were enrolled in science disciplines. Xavier has been particularly successful in placing these students in biomedical professional schools and graduate schools of science.

In 1993 Xavier was number one nationally in placing African Americans into medical schools, Dr. Hunter said. In the past, 93 percent of these students who did go to medical school graduated or are still persisting and on track.

In 1994 the university placed 157 graduates in science-related graduate or professional schools, including 12 in biology or chemistry graduate programs and 55 in medical schools. The high placement figures result in large part from the university's success in preparing African Americans for these schools. Nationally, 27 percent of African American college freshmen with ACT scores of 24 or higher eventually enter graduate or professional schools. At Xavier, however, 57 percent of such freshmen go on to medical school alone.

Four activities comprising an educational pathway—supported in part by HHMI grants—play key roles in the preparation of Xavier students for graduate work in biomedical sciences, said Dr. Hunter. The first is the Summer Science Academy, offering problem-solving-oriented programs for students in grades 8 through 12. MathStar, BioStar, and ChemStar prepare students for high school algebra, biology, and chemistry.

SOAR (Stress On Analytical Reasoning) prepares students for college-level academics.

The second activity, known as Triple S (standards with sympathy in the sciences), provides support for underprepared Xavier students in entry-level biology, chemistry, mathematics, and physics courses without compromising standards. The support comes from modifications in the curriculum, including course standardization, inquiry-based laboratories, monitoring of students' academic progress, and encouragement of group studying.

The third is the Biomedical Honors Corps, a systematic effort to identify African Americans with interest and ability in the sciences and to provide them nonacademic support to improve their chances of getting into graduate and professional schools. Workshops give Honor Corps members information on which courses to take, where summer programs are offered, how to apply to graduate schools, and what careers are available in science.

The fourth activity is the Science Education Research Group, a voluntary association of mathematics and science faculty who meet weekly throughout the academic year to plan, coordinate, implement, evaluate, and modify the first three activities.

To get faculty involved in these activities, Dr. Carmichael explained, program administrators in some cases provide administrative and intellectual support, help secure professional recognition, and offer faculty their choice of tasks to undertake. Many faculty at Xavier need only to be convinced that their efforts will be worthwhile before they become involved in the activities, he said. In one instance, 25 faculty members from four departments turned out on a Saturday to help write vocabulary-building exercises for the students. Members of the physics and mathematics departments were significantly involved, as well as those from biology and chemistry.

One obstacle to faculty involvement in outreach and precollege activities has been a perceived lack of professional recognition for their contributions, Dr. Carmichael said. Some faculty still view research and publication as the chief route to professional advancement. But Xavier is a relatively small school and recognizes teaching and related activities when considering tenure and promotion. And program coordinators make sure that administrators know when faculty contribute to the program.

The program tries to encourage faculty to participate by asking them for suggestions and giving them choices. Some typical questions are: What do they want to do? Would they like to contribute to one of the special text books for the program?

Drs. Jacqueline Hunter, JW Carmichael and Deidre Labat of Xavier University of Louisiana describe their strategies to involve faculty members in their successful precollege programs for attracting minority students into science.

Would they prefer to rewrite one? The program makes it clear that faculty will receive recognition for participating.

The program also tries to make participation easy for faculty by assuming the administrative work. In 1994 student workers in the premedical advising office processed around 2,000 summer program applications, ordered books, and handled most other administrative chores. Dr. Carmichael admitted that summer programs were especially difficult to run, primarily because the administrative support normally available during the academic year is often lacking during the summer.

One of the most effective means of bringing faculty into the program has been the Science Education Research Group. It includes faculty from several departments, provides a forum for discussing issues in science education, and serves as a support group for faculty interested in exploring better ways to teach science and in publishing their results. The group also functions as a vehicle for ensuring that such activities are reported to and recognized by the administration. Dr. Carmichael said that faculty participating in these programs now include this experience in their résumés for tenure and rank review.

Dr. Labat cautioned, however, that not every professor at Xavier "buys 100 percent" into the activities. Some faculty members in biology, chemistry, and mathematics still spend most of their time writing grant proposals and conducting

Dr. Graham Walker, Massachusetts Institute of Technology, offers a view from the audience during a plenary session.

research and do not actively participate in the programs.

Discussion

Faculty Involvement as a Factor in Tenure. Participants raised questions concerning faculty expectations and rewards in regard to involvement in precollege and outreach programs. Dr. Hunter replied that Xavier faculty are given tenure based on teaching, scholarship, service to the university, and service to the community. The rank and tenure committee has recognized as research publications more than 30 papers by members of the Science Education Research Group. The group itself is a university committee, so membership in it counts as service to the university. Teaching in the Summer Science Academy is considered service to the community. And at Xavier, teaching ability is valued highly and an important consideration in tenure review.

Dr. Michael Wells reported that his department at the University of Arizona has attempted to recognize officially the activities involved with science outreach and science education. For new faculty, a letter of offer toward tenure serves to outline professional responsibilities for tenure in spelling out which activities will be considered.

Providing an Infrastructure for Outreach Faculty. Participants asked about the type of infrastructure needed to maintain the Science Education Research Group as a viable entity. According to Dr. Carmichael, the nucleus of the group consisted of the faculty who have spent considerable time together developing SOAR, the first of the Summer Science Academy programs. The program is officially run out of the office of the chair of the chemistry department; however, much of the secretarial work is done by the office of the premedical adviser, Dr. Carmichael, who noted the benefits of collaboration between the chemistry and biology departments for premedical majors.

The group has been particularly useful in improving communication among departments, Dr. Labat added. If a professor does not return student papers, for example, the omission is often corrected by relaying word through the group to the dean. Students need regular feedback from papers and tests to let them know how they are doing in their courses, she said. Faculty also use the group as a place to coordinate the timing of examinations in entry-level courses. Dr. Labat found that it was advantageous for freshmen to receive biology tests on different days than chemistry tests, for example. However, students in upper-division courses may receive two or more tests on the same day.

Getting Into the Academy. Participants asked how high school students are selected for the Summer Science Academy and how they do when they return to their regular classes. Dr. Carmichael replied that in his experience program coordinators look for about a 2.75 GPA in science, mathematics, English, and history courses for the last semester before application. About every two years, questionnaires are used to find out how well Academy graduates are doing in high school. The students, their parents, and teachers uniformly respond that the Academy helped improve academic performance, and the teachers often ask whether they can get more students into it.

Motivating Students Towards Graduate School. Dr. Graham Walker of the Massachusetts Institute of Technology pointed out the relatively small proportion of Xavier science students going on to graduate school, compared with the relatively large number going into medical school. He asked whether more students could be steered toward graduate school. Dr. Carmichael replied that when high school students in a sophomore biology class are asked what professional school they intend to enter, 75 percent will say medical school and fewer will say engineering, but fewer still will indicate interest in a Ph.D. program.

Xavier science faculty are trying to interest more students in pursuing graduate school by arranging research experiences and ensuring they are registered in the office on campus dedicated to getting students into graduate school, Dr. Labat said. But it is also important that science faculty be good motivating models for graduate school.

The Role of Science Departments in In-Service Science Education

Smith College ■ Thomas S. Litwin, Ph.D., Casey Clark, M.Ed.
University of Colorado at Boulder ■ Mark William Dubin, Ph.D., Julie Graf
University of Wisconsin–Madison ■ Paul H. Williams, Ph.D., Andrew J. Petto, Ph.D.

The session featured three in-service programs supported by HHMI. Presenters described their institutional contexts and identified some of the factors affecting institutional commitment to their programs and program stability. At Smith College one of the main goals was to become part of the college's core mission. At the University of Colorado at Boulder, it was thought crucial to maintain strong connections between program components and draw on the full array of departmental resources. For the University of Wisconsin–Madison, key issues included the need to ensure science faculty involvement and provide a network for teachers to augment and sustain the summer teacher enhancement activities.

Presentations

Smith College. The Smith College program, Current Students/Future Scientists and Engineers, was influenced by a model from *Investing in Human Potential*, a publication of the American Association for the Advancement of Science (AAAS). Recognizing that an isolated program is more difficult to sustain than one that is part of an institution's core mission, the basic goal of the model is to build strong ties between a new program and the factors that determine whether it will be stable and accepted institutionally, both of which are essential to its long-term prospects.

Dr. Thomas Litwin described the evolution of a program through several stages on its way to occupying a place on the institution's organizational chart. Three years ago, science outreach was not on the organizational chart of the Clark Science Center at Smith. According to Dr. Litwin, now it is part of the "ebb and flow" and "has a seat at the table." He explained the program in terms of a theoretical pyramid: the bottom layer of the pyramid is a broad foundation of visibility among administrators, faculty, and the development office within the institution. This supports the next layer, which is identification with mainstream activities in institutional planning meetings and other activities in the administrative and budget decision process. Such recognition is a prerequisite to acquiring access to institutional resources not ordinarily allocated to isolated programs. Coordination with fundraisers and other sources of support is necessary to maintain the program's resource base, a central ingredient in reaching stability and permanence, which is the apex of the pyramid.

Casey Clark gave an overview of the HHMI initiative, including the program's goals to encourage women and underrepresented minorities to enter science. She delineated the participants (teams of teachers and counselors) and the timeline (a year-round program involving summer training workshops, school-year implementation plans, spring follow-up sessions, and a final report from each team).

University of Colorado at Boulder. Julie Graf outlined the goals of each of the program components of the HHMI in-service initiative at Boulder (see chart below), describing each component in terms of the role of science departments. She noted that the in-service program draws on the entire array of resources of a department; not just the faculty, and that the benefits of the program extend not just to the precollege teachers but also to the university faculty and students. The university also offers mini-grants to provide science equipment in precollege classrooms.

Ms. Graf identified several strategies that have been critical to the success of teacher training programs at the university. These strategies include offering a menu of multifaceted, interconnected opportunities so that all participants can design their own level of involvement; emphasizing hands-on, quality science content; working directly with teachers, as opposed to only administrators or other school system personnel; seeking and responding to the teachers' expressed needs; promoting collaboration among teachers; employing people who bridge the precollege and university cultures; recognizing and acknowledging the mutual benefits of partnerships; and providing continuity and follow-up.

Ms. Julie Graf and Dr. Mark William Dubin of the University of Colorado at Boulder advise their colleagues to tap the full array of departmental resources when offering in-service teacher development programs.

University of Wisconsin–Madison. There are approximately 800 biologists in six colleges at the University of Wisconsin–Madison, but there is no separate department of biology to provide resources to precollege teachers. Five years ago the university matched HHMI funding to establish a faculty-conceived Center for Biology

University of Colorado at Boulder

Goals	Role of Science Department
Courses and Workshops	
■ Update teacher knowledge in science ■ Exposure and access to University research ■ Hands-on experience that is transferable to the classroom ■ Contact with faculty ■ Forum for sharing ideas with other teachers	■ Access to faculty expertise, faculty input, and equipment ■ Exposure to precollege teaching realities ■ Experience with the latest education and learning techniques
Science Squad	
■ Gain experience in schools ■ Support teachers in hands-on science activities ■ Serve as role-models ■ Apply substantive expertise	■ Organize and oversee student participation ■ Provide access to resources, expertise, laboratory facilities, and equipment
HHMI Bioscience Institutes	
■ Expose inner-city high school students and their families to university laboratories and campus ■ Increase teacher experience in hands-on science ■ Tailor each institute to a particular school ■ Allow students to showcase their science skills for their families	■ Research expertise, facilities, and equipment ■ Practical experience for under-graduate and graduate students ■ Offer lectures and campus tours
Scientist-in-Residence	
■ Provide source of scientific information and expertise on laboratory experiments for precollege teachers and university faculty ■ Serve as bridge between precollege-level and introductory-level science at the university ■ Encourage and initiate hands-on, inquiry-based activities at both levels	■ Laboratory and office space for the scientist-in-residence ■ Access to departmental resources and expertise
Summer Research Opportunities	
■ Engage teachers in scientific research processes ■ Promote direct connection between precollege teachers and researchers ■ Train teachers in inquiry-based learning, problem-solving, and laboratory techniques	■ Research placements for teachers ■ Mentoring by faculty and laboratory personnel ■ Supplies

As Ms. Casey Clark and Dr. Thomas S. Litwin of Smith College look on, Dr. Paul H. Williams describes the Institute-supported teacher enhancement activities at the University of Wisconsin–Madison.

Education at the university. One challenge for the center, according to Dr. Paul Williams, is to forge the resources and expertise of individual faculty into effective in-service programs for teachers. This is particularly difficult because the center is not an academic office and has no authority to compel faculty participation. Consequently, faculty involvement depends on a shared view of teacher training as a critical need in science education.

With HHMI support, the center developed a series of in-depth, one- to two-week enhancement programs for biology teachers as part of the university's Summer Science Institute. Between June and August, the institute offers 48 different programs covering a spectrum of subjects, including human genetics, special education, molecular and cell biology, biotechnology, environmental science, plant biology, health and basic science, and substance abuse. Teachers receive graduate credits, tuition waivers, resource materials, and in some instances stipends. To help teachers sustain their experiences, the center also developed BioNet, a program of regional networks of scientists, institutions, and businesses that relies on "lead teachers" to organize meetings and other avenues for communication on regional issues related to science. All indications are that the program is extremely successful; a formal evaluation is currently being conducted to assess its specific impacts.

Drawing from the Institute for Multicultural Science Education program of the National Science Foundation, the center's activities also focus on reaching teachers and administrators in underserved areas and on infusing its programs with multicultural perspectives. The objectives are to change the culture of science as well as to extend services to underserved communities.

Dr. Williams indicated that some of the entrepreneurial aspects of biological research can be channeled into resources for teacher training. He described the seven-year-old Wisconsin Fast Plant program that stems from his own cabbage-breeding innovation of 25 years ago, when in the course of searching for basic genetic information about cabbages, he bred a plant that grows extremely fast. The plant is a particularly good classroom subject for illustrating an organism's life cycle and other aspects of biological development.

The University of Wisconsin program extends its impact through the use of master teachers and regional teams of faculty, scientists, and administrators who conduct teacher training throughout the country, as well as through dissemination of fast-plant materials at national teachers conferences. Technical assistance is provided through an 800 phone number and a newsletter now reaching 25,000. The newsletter is also available on Internet. The program has its own in-house evaluators, but evaluations of other materials and training activities developed by the university are also being considered.

Discussion

Gaining Institutional Commitment. The greatest and most common concern noted by the program coordinators is to gain institutional commitment so that their teacher-training and outreach programs will become permanent parts of the core of their colleges and universities. In the process of reaching this goal, they must confront a range of issues, from philosophical questions to budget constraints and demographic trends, and they must establish a successful track record as well as develop realistic and convincing plans for continued effectiveness.

Some of the points that emerged from the discussion included the following:

- The current tight fiscal climate may be forcing institutions to choose between the need for innovation versus supporting successful already-established programs in teacher training and outreach.
- As enrollment in science increases, institutions may not be as committed to reach into the schools to attract more underrepresented minority and women students to science unless there is a permanent commitment to such outreach efforts.
- In-service and outreach programs are particularly vulnera-

ble to budget cutbacks because they are inherently expensive. They are labor-intensive and often must cover the costs of materials and equipment for science activities. This is seen as another reason to ensure a strong institutional commitment for these programs.

■ There are interim levels of institutional commitment. For example, Dr. Litwin indicated that an institution can provide sufficient support to allow someone in his position to attract other sources of funding. The institution can also form partnerships or alliances with other organizations that can share responsibility for the teacher training and outreach.

School Administrators. The panelists and the audience discussed the importance of maintaining contact with precollege administrators—including system-wide and school-based science coordinators—and involving the administrators whenever possible. For example, administrators are often part of the school teams participating in the Smith program. Administrator support is important for generating interest and leveraging funding for the science education training program. However, Dr. Dubin and Ms. Graf cautioned that the outreach programs should not go to the administrators at the outset; in establishing the programs, they should work with the teachers first. The "top-down" approach, in their view, has been successful.

Graduate Students. There are several roles in teacher-training programs for graduate students from both science and education departments (and for graduate students involved in both). One role is as a resource for scientific expertise; another, as a resource for educational techniques effective in teaching science. While providing an ongoing presence for science education in the schools, graduate students are also exposed to the realities of teaching.

For education majors in particular, the in-service training programs are a valuable preservice opportunity to learn hands-on science activities. Dr. Williams described his institution's science education scholars program, which offers students mentoring from three different perspectives: research faculty, master teachers, and department faculty.

Preparing Tomorrow's Science Teachers

Oberlin College ■ David H. Benzing, Ph.D., Dennison Smith, Ph.D.
State University of New York at Binghamton ■ Anna Tan-Wilson, Ph.D., Herbert Posner, Ph.D.
University of Nebraska–Lincoln ■ Eric Davies, Ph.D., David T. Crowther, M.Ed.

The panelists discussed three programs that approach training for future kindergarten through 12th-grade science teachers in different ways. Oberlin College, which does not offer an education major, attempts to interest science majors in precollege teaching by having them work with 1st- through 7th-grade teachers in the local public schools. The Oberlin students help to teach year-long science modules. At the State University of New York at Binghamton, a special program gives teaching experience to juniors and seniors majoring in biology and biochemistry. The upper-division students are provided the opportunity to design experiments, develop materials, and assist in teaching first- and second-year college students taking introductory biology courses. The University of Nebraska–Lincoln's program is focused on students who have already decided to make teaching a career: elementary education majors. Its goal is to present science to prospective elementary teachers in such a way that their discomfort with or even fear of science can be abated.

Presentations

Oberlin College. Dr. David Benzing noted that 15 to 20 years ago Oberlin graduated many elementary school teachers. However, the college dropped its teacher certification program about a decade ago because of declining student interest and changes in requirements for certification in Ohio and other states. With renewed student interest in precollege teaching, Oberlin has launched a new preservice program to address the college's community service mission.

The primary goal of the program is to encourage students majoring in the biomedical sciences to pursue teaching careers by giving them the opportunity to teach science in the public schools. At the center of the program are teams of public school teachers, Oberlin science majors, and Oberlin faculty, who serve as a resource.

In 1994 a total of nine teachers from the Oberlin public schools in grades 1 through 7 were organized into five projects. In the spring they worked with Oberlin faculty and seven undergraduate seniors to prepare year-long teaching modules. In the fall the teachers began to use the modules in their classroom teaching with the assistance of the Oberlin students. Some of the teachers worked with the Oberlin faculty and students to create new modules. Others used existing instructional material, but modified it to meet their special needs.

In general, the Oberlin students—including majors in biology, neuroscience, and physics—assist in specific classroom activities, rather than functioning as student teachers. Instead, they assist with the hands-on science activities that are a part of projects in all the classrooms.

The program has attracted student interest, Dr. Benzing said, drawing 18 applicants for the seven student slots. He added that he hopes next year to recruit additional teachers to participate and to include teachers of grades 8 and higher. He also expressed the hope that the teams would continue operating, so that Oberlin would be able to maintain a regular stream of students into the local schools.

Dr. Benzing noted that the project had not gone as smoothly as initially planned. In retrospect, the program would have been better served if the college had directly approached the teachers rather than the school administration. Teachers' understanding of the program's goals, structure, and activities were substantially enhanced as a result of direct communication.

State University of New York at Binghamton. Drs. Anna Tan-Wilson and Herbert Posner of the State University of New York at Binghamton discussed the Teaching Scholars Program, which gives upper-division biology and biochemistry majors the opportunity to participate in the teaching of introductory laboratories for first- and second-year college students. Its dual goals are to give undergraduates the experience of teaching and improving introductory biology laboratory courses through the participation of students.

The program recruits junior and senior biology or biochemistry majors in the top 25 percent of their class who are interested in gaining teaching experience. No prior laboratory teaching experience is needed. One third of the participants are underrepresented minorities, according to Dr. Tan-Wilson.

The students take a six-week summer seminar where they work in laboratories to help faculty develop new investigative projects that can be used in the introductory courses, revise the laboratory manuals, and discuss teaching techniques. They receive a stipend during the six-week seminar.

Dr. Posner noted that during that seminar, students had suggested improvements in laboratory experiments to make them more "user-friendly" for first- and second-year students. During the 1994 session, for example, one participating student modified an experiment on light-induced proton gradients in chloroplasts so that beginning students could complete the required experiment in only three hours.

In addition to the summer program, where students worked on

\pproaches for developing tomorrow's science teachers are explained by some of today's HHMI program directors: Drs. Eric Davies, University of Nebraska–Lincoln; Anna Tan-Wilson, State University of New York at Binghamton; and David H. Benzing, Oberlin College.

subject matter, they take a course on education theory and practice to help them with the day-to-day teaching. The course—Educational Theory and Practice for Teaching Assistants—is taught by Dr. Posner of the Department of Biological Sciences, and Dr. Thomas O'Brien of the School of Education. The 16 class sessions cover a range of topics, including cognitive psychology and the constructivist theory of learning, misperception research, concept research, ways to help students with problem solving, evaluation techniques, learning styles (with special implications for women and minorities), and student-teacher relationships.

After the summer seminar, the students are paired with graduate students to help teach the introductory biology laboratory classes. They receive course credit for this work. The undergraduates also have an opportunity to tutor students from local high schools.

Dr. Tan-Wilson says the program has yielded clear benefits for participating students, including improvements in laboratory and teaching skills, problem solving, and particularly science, pedagogy, and written and oral communication. Moreover, she noted, the program has provided students with an enjoyable teaching experience that has strengthened their self-confidence.

Dr. Tan-Wilson also reported anecdotal evidence that the experience has encouraged some of the students to consider teaching as a profession.

The program has brought benefits to the introductory classes, the program directors noted. These include the development of more student-friendly laboratory materials, and a higher rate of successful student experiments. First- and second-year students have been able to work with well-prepared and enthusiastic teaching assistants.

University of Nebraska-Lincoln. According to Dr. Eric Davies of the University of Nebraska-Lincoln, the recipe for success for Biology 295, newly developed for elementary education majors, included finding a low-key manner of introducing the course.

Dr. Davies explained that he and his colleagues, though creating a brand new course, gave it a number that was already in use. They did not have to obtain faculty approval for a new course and avoided having to overcome potential faculty skepticism of the project. Biology 295 consists of a series of four-hour hands-on laboratories and what Dr. Davies called an "enthusiasm-based lecture series." In addition, one-hour lectures are given by faculty members who are invited to talk about their current research and tell the students why they are excited about it. The laboratories, explained Dr. Davies' colleague, David Crowther, include experiments, creative writing projects, and discussions designed to allow students to be active participants.

The course has received an enthusiastic reception from the elementary education majors, which Dr. Davies traced to several factors. First, he said, it uses a team of effective instructors, including James Landon, a former high school teacher from Seward, Nebraska, and the associate director of HHMI precollege programs at Nebraska; David Crowther, an instructor at the Nebraska Teachers College and former elementary school teacher in Utah; and Kathy Jacobwitz, a 7th–12th-grade science teacher at a local high school. The students in the course appreciated hearing from instructors with classroom experience.

Dr. Davies said that the hands-on approach used in the course also explained its success. In his words, the course treats science not just "as a noun," i.e., as a body of knowledge, but as "a verb," i.e., as a process of learning. Science is both, but too many courses focus only on the former, according to Dr. Davies. He explained that in treating science as a verb, the course is very careful about which verb it is. The course did not just "cover" topics, he said. Instead, Biology 295 helps students "uncover" ideas for themselves and "discover" ideas and concepts by doing science hands-on.

It was critical to create a new course that was hands-on and aimed at elementary education majors, Dr. Davies explained, because studies have shown that students are most likely to be turned off by science in elementary school. When children fall away from science they may be influenced in part by teachers who are not comfortable with the subject.

In discussing the problems the course faces, Dr. Davies returned to the notion of underplaying its innovativeness. He said that some members of the science faculty were skeptical about the course simply because "it's different from what we always do," and possibly because faculty are used to courses that have 150 students, are based on lectures, and use graduate students to run laboratories. But a course will only reach future elementary school teachers, Dr. Davies stressed, if it is small and hands-on and puts the students, not the subject matter, first.

Other problems included how to institutionalize the course and how to evaluate it. The two were linked, Dr. Davies said, because there would be no point in institutionalizing the course if there were no way to evaluate it. If the course does prove valuable, however, it will be necessary to find support to keep the program going after the HHMI grant runs out. A related problem is how to develop a cadre of teaching assistants that can give the students the kind of help they need.

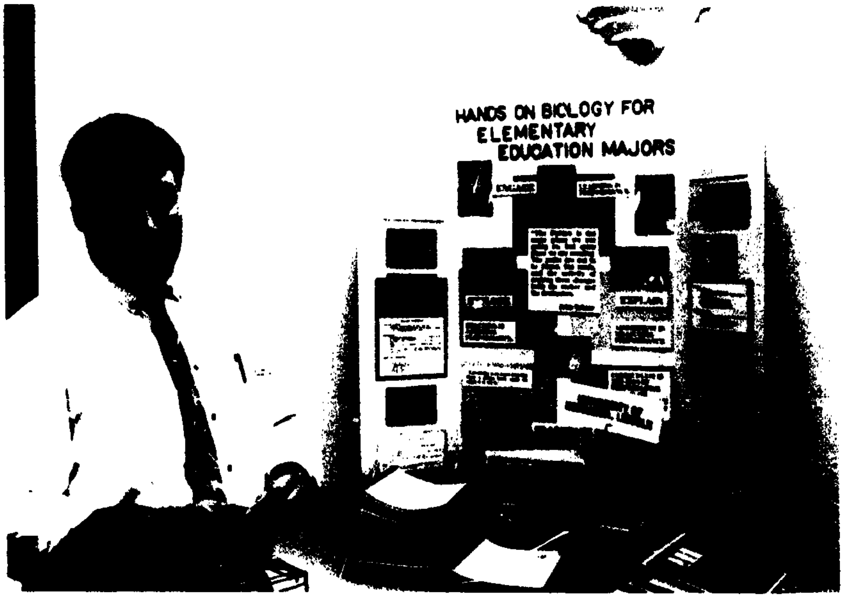
Dr. Davies concluded by saying that the course has changed student attitudes about science from predominantly negative to universally positive. He also reported that the university is gathering data about students' performance on standardized tests as well as their attitudes toward science and preparedness for teaching science. The data will become the focus of a Ph.D. thesis.

Discussion

During the discussion, the panelists provided more details about their programs. David Crowther explained that in the University of Nebraska's Biology 295, there are three levels of experiments: short ones done in a single class; medium ones lasting two or three sessions; and long-term ones, such as a unit on plant growth, that can last two months. Mr. Crowther said the course used a discovery-based approach and that students were required to keep a laboratory journal. The Biology 295 instructors make a point of posing questions to the students that encourage them to reflect about what they have learned, and especially to think about ways to use in their classrooms what they have learned in the course.

Mr. Crowther also explained that Biology 295 is but one part of the science-related preparation that education majors receive. While Biology 295 helps provide the students with content, other courses provide instruction on teaching methods and pedagogy. Mr. Cro her also emphasized that the University of Nebraska education majors receive experience in classrooms very early in their studies and that mathematics was fully integrated into Biology 295.

Peer-Teaching: Quid Pro Quo. Dr. Herbert Posner provid-



Mr. David T. Crowther explains the University of Nebraska–Lincoln's program for developing future science teachers.

ed more details on what the introductory laboratory courses had gained from the Teaching Scholars Program, reporting that the students had created much more computer-friendly laboratory manuals and other classroom materials. In particular, he said, one student with no computer background had rewritten the instructions for a computer program to do a chi-square analysis. The new version was much easier for the students to understand and use.

In response to a question about whether undergraduates minded being taught by other undergraduates, Dr. Tan-Wilson said that, on the contrary, they liked being taught by their peers. Moreover, she explained that during the school year, the students met four hours a week with the faculty member who was teaching the basic course, ensuring their mastery of the material. Dr. Posner added that in the laboratory sessions, the students used cooperative learning techniques, breaking up the class into learning teams.

Several discussants noted the advantages of using undergraduates as teaching assistants in science courses. Dr. Barbara Sawrey of the University of California–San Diego reported that her university used about 90 undergraduates as teaching assistants in science courses. They earn academic credit for their work with students, she said, and the students who demonstrate special interest and talent in teaching are taken on as paid discussion section leaders. They turn out, she said, to be the best teaching assistants.

Dr. H. Craig Heller of Stanford University said that in their human biology department, all the courses use undergraduates as teaching assistants. They have been highly successful, Dr. Heller added, and the students are enthusiastic about their peer instructors.

Other Preservice Programs. The participants in the discussion also compared and contrasted the experiences of preservice programs at other colleges and universities. Dr. Michael Wells of the University of Arizona noted that the dean of sciences at his institution had taken on an essential role in the training of science education majors. Working with the science departments, the dean helped set up science courses specifically designed for future kindergarten–12th-grade teachers, including one on how the future teachers could translate what they learned in lecture classes into classroom exercises for their own students.

Dr. Davies responded that at the University of Nebraska cooperation between the Teachers College and the science departments had been excellent and that he believed such collaboration was necessary for success.

Dr. Edward Cox of Princeton University reported that Princeton had long had a program under which students could earn a teaching credential in four years, spending part of that time teaching at a local public school. He reported that the university was experimenting with a new program under which students pursuing this credential could earn laboratory credit in a science course by preparing a precollege science course curriculum. He suggested that most universities might require their science students to teach in kindergarten–12th grade.

Dr. Robert Parsons of Rensselaer Polytechnic Institute reported that his institution had been working with the New York State government to set up a program under which RPI science majors could earn a teaching credential.

Programs for Community College Faculty and Students

Arizona State University ■ James Collins, Ph.D., Steven W. Rissing, Ph.D.
University of California–Davis ■ Merna Villarejo, Ph.D., Mark G. McNamee, Ph.D.
City University of New York City College ■ Sharon Cosloy, Ph.D., Joseph Griswold, Ph.D.

Dr. Merna Villarejo of the University of California–Davis framed the discussion by presenting data showing the growing enrollment at community colleges. Dr. James Collins described how the HHMI-funded program at Arizona State University is bringing inquiry-based instruction into the biology curriculum and involving community college faculty in the process. Dr. Villarejo outlined the program at University of California–Davis, which offers community college faculty a sabbatical for intellectual renewal and help in revising their departmental curriculum. Dr. Joseph Griswold of the City University of New York City College explained the HHMI-supported summer bridge program to help community college students transfer successfully into a biological science program at the university level. Discussion addressed problems resulting from disparities between two- and four-year institutions, such as conflicting missions, differing student performance assessments, and variation in the quality of departments in community colleges. Participants noted that community college faculty are often excellent teachers but that university faculty are seldom willing to learn from them. Participants also explored the rigor of inquiry-based instruction, the success of various programs in retaining transfer students, and the prospects for continuing such outreach programs after external funds are spent.

Presentations

Arizona State University. The HHMI-funded portion of the Undergraduate Biology Education Program at Arizona State University focuses on development of both university and community college faculty and a critical-inquiry–based curriculum, Dr. Collins said. In its first summer, the HHMI program involved only university faculty, with 14 attending a monthlong workshop devoted to critical inquiry. But considering Arizona State's high proportion of transfer students, the university realized that it should include the community colleges also and focus on the introductory course for majors.

Arizona State serves a community college district with 12 colleges and 83,000 students, Dr. Collins said. By 2010, the district will have 120,000 students. The community colleges provide a particularly important pathway into four-year universities for Native Americans.

In the next year, the HHMI program offered a teaching strategy workshop emphasizing critical inquiry, which was attended by life science faculty from 9 of

Drs. Joseph Griswold of the City University of New York City College, Merna Villarejo of the University of California–Davis, and James Collins, Arizona State University, describe how they address "transfer shock"—the initial drop in grades sometimes experienced by community college students enrolling in university science programs.

the 12 district community colleges. The workshop included a week of training in teaching science as it is practiced, two weeks focused on creating and presenting laboratory exercises, and another week involved with preparing written materials. The HHMI program aims to establish critical inquiry throughout the biology curriculum for all students and to extend it to the community colleges.

Nationally, said Dr. Villarejo, enrollment in public two-year institutions (approximately 5.5 million) nearly equals that of public four-year institutions (approximately 5.9 million), and the number of students transferring from community colleges to become juniors in universities is increasing. Twenty-five percent of graduates from the University of California–Davis and 40 percent of those from Arizona State had completed two years at a community college. Dr. Villarejo cited those figures to underscore the importance of participation by community college transfer students, because many are from underrepresented minority groups.

The difficult financial situation of higher education in many states suggests that community college transfer students will constitute an even larger fraction of university populations in the future, Dr. Villarejo said. A community college education is less expensive for students, who can often live at home. And it is less expensive for taxpayers. Annual tuition and fees at public four-year institutions average more than $2,300, whereas the costs at two-year institutions are less than half that amount.

She emphasized that the quality of the preparation of community colleges is critical. In particular, the science education the students receive determines how well prepared they will be for specialized courses at the university level.

University of California–Davis. The University of California–Davis has a situation similar to that of Arizona State but approaches it differently, focusing on three community colleges that feed large numbers of students into the university, Dr. Villarejo said. When the program began, community college faculty said that, above all, they needed intellectual renewal. At Sacramento City College, no biology faculty had been hired in 20 years and no one there had had a sabbatical in that time. These factors, combined with heavy faculty teaching loads, make it difficult for the department to keep abreast of the latest developments in biology.

Intellectual renewal thus became the primary theme of the university's partnership with community colleges, and curriculum renewal became the secondary one. The program does not work with individual faculty but with the department as a whole.

As part of the application process, community college faculty submit a written proposal of what they will do for their own renewal. None so far has chosen to do research. Rather, they have opted to take courses. They also participate at some level in introductory biology by teaching subjects in which they specialize.

Dr. Villarejo pointed out that many community college faculty are more skilled at teaching than the university faculty. A goal of the program is to make the collaboration a two-way street. However, this aspect of the program requires further attention and development.

The two-quarter sabbatical at the University of California–Davis includes time for community college faculty to revise the courses they teach and think about revisions for their curriculum as a whole. They also create a plan for modernizing their laboratories, and the program provides funds for new equipment.

City University of New York City College. City College, an institution within the City University of New York system, accepts students who transfer after two years in one of the community colleges of the CUNY system. Historically, many of these students are underprepared for University science, Dr. Griswold said.

The college therefore designed a summer bridge program to help community college students succeed in transferring into the biomedical sciences at City College. The three-week program exposes students to university-level biology and chemistry, develops their academic skills, and introduces them to City College's environs, people, and operations and to its special programs and services. The program also helps them complete applications, transfer credits, and register for courses.

68

The summer bridge program emphasizes collaborative learning, with students working together on many of their projects. The students are organized into teams under the leadership of an upper-division student, and once a week they hold group-building competitions—an idea picked up from the HHMI-supported program at Xavier University of Louisiana. Teams also earn points throughout the week for performing well in academically related activities.

According to Dr. Griswold, the program conveys to students the level at which they are expected to perform, and also what kind of academic habits and professional responsibility are expected of them when they attend City College.

A secondary goal of the program is to establish better contacts between science departments at City College and the community colleges, he said. Community college faculty often feel they are considered second-class citizens in the CUNY system. Dr. Griswold and his colleagues view this as an important problem they hope to address through the program.

Discussion

Articulating Performance Assessment and Teaching Expertise. Participants agreed that one difficulty in dealing with transfer students is that the requirements for completing community college science courses differ from those at a university. According to Dr. Griswold, community college science faculty have remarked to him on the significant differences between their course examinations and the College's.

The summer bridge program therefore exposes transfer students to the kind of performance assessment they will be facing when they take biology and chemistry at City College, he said. The focus on rigorous testing in the bridge program has also prompted some community college faculty to rethink their own standards and assessment of performance. Several have worked at City College through a faculty exchange program and have taken the course outlines and examinations back to the community college to use with their own students.

Also, community college faculty who have taken the sabbatical at the University of California–Davis say their own courses have been more descriptive and less quantitative than those at the university, Dr. Villarejo said. These faculty are now revising the courses they teach in community college. She noted a definite change in the content of community college courses toward more quantitative science, which will ultimately benefit students.

Community college faculty often have considerable teaching expertise that can be shared with university faculty, participants noted, but the latter usually do not take advantage of it. At the University of California–Davis, the faculty hosts for visiting community college professors might gain from their guests, Dr. Villarejo said. More could be done to foster participation by university faculty in this regard.

Eliminating Transfer Shock. Community college students often undergo a "transfer shock" when they come to the University of California–Davis, Dr. Villarejo said. Their grades fall precipitously for a quarter or two and then recover. It is hoped that the curricular adjustments and the increasingly close contacts with community college faculty will reduce or eliminate this effect.

At City College, Dr. Griswold said, transfer student success follows a reverse pattern. Students taking the summer bridge program generally outperform other students in the biology course they take the following fall. Despite this auspicious start, there tends to be some fading in their performance as they get to the upper-level courses, he said, indicating that the initial intensive intervention for three weeks is not enough and systematic follow-up is needed as the students go on.

Some participants said they had more of a problem dealing with the uneven preparation of community college students. Some are strong in chemistry but weak in mathematics and biology; some are strong in biology but weak in chemistry and mathematics, said Dr. Orville Chapman of the University of California–Los Angeles. The net effect is that students from some departments do better in university science programs because of the variation in level of departments at a given institution.

Dr. Villarejo suggested an interdepartmental science education group of the type described in the presentation by Xavier University as a useful model for dealing with this issue. The group could identify areas at community colleges in need of development. The HHMI program, for example, would aim at community college biology departments.

Choosing a Community College Partner. One participant described the problem of having to deal with three different community college systems in Wisconsin: traditional two-year colleges, technical colleges, and tribal colleges. Other participants said they did not face that problem because the community colleges are generally under the same state charter. Dr. Villarejo suggested that universities focus on the community colleges that send them the most students.

Institutional Commitment. A participant asked whether the universities would take over the funding of the community college outreach programs when external funding ends. Dr. Villarejo said the program is already leveraging other funds. The curricular reforms have persuaded some community colleges to offer more money for sabbaticals. The reforms have also led to new hirings in the biology department at Sacramento City College. One highly-sought professor came specifically because of the College's relationship to the University of California–Davis.

A Measure of Success. Participants asked how successful any of the programs have been at retaining transfer students in university science programs. Dr. Villarejo replied that the University of California–Davis program has not yet been assessed but that indirect evidence suggests it is succeeding. The university revised its biology curriculum recently, and Sacramento City College did a parallel revision, so articulation into the university has begun.

A Look at Critical Inquiry. Another participant questioned the rigor of the inquiry-based approach relative to traditional approaches. Dr. Collins said that the approach as used at Arizona State University basically involves teaching science as science is practiced, as opposed to memorization of facts. Critics of the inquiry-based approach often assume that it ignores content, he said, but a certain amount of content is required in order to do the science.

A technique to help establish inquiry-based instruction is to reverse the order of courses, putting students into the laboratory before they have had the lecture, said Dr. Steven Rissing of Arizona State University. In such cases, it is helpful to tell students that they are being put into an inquiry situation on purpose and may feel a little lost, but that they are not expected to know everything. Dr. Rissing said that the approach requires students to ask questions and to proceed without a textbook.

Some of the biology faculty at Arizona State, Dr. Collins said, hope to teach students the process of doing science, including how to search the literature. In more advanced courses, they will be better prepared to function as a scientist.

Teaching with an inquiry-based approach is more difficult than traditional approaches, he said, requiring faculty to have the confidence to take discussions where they go.

According to Dr. Griswold, instructors also have to be able to make snap judgments about whether to follow a line of questioning raised by a student or to reject it and continue in the planned direction. He said that hard inquiry-based instruction puts students on task and obviates free-floating discussion. In addition, the instructor is there each step of the way guiding what students may be looking at and discovering.

Educational Technology: Supplementing Laboratory Instruction

Beloit College ■ John Jungck, Ph.D.
Harvard University ■ Stephen C. Harrison, Ph.D., Scot A. Wolfe
University of Puerto Rico Mayaguez Campus ■ Juan G. González-Lagoa, Ph.D., Juan López Garriga, Ph.D.

HHMI is supporting the development of new educational technologies at colleges and universities across the country. During 1995, the Institute will work with program directors to identify and disseminate information on these technologies, in order to spread the word about exciting new approaches and to avoid costly duplication of effort. The presenters in this session described examples of Institute-sponsored programs using technology to supplement laboratory instruction.

Presentations

University of Puerto Rico Mayaguez Campus. A fundamental goal of the outreach program of the University of Puerto Rico Mayaguez Campus is to attract students to research. The first obstacle for the program to overcome was what Dr. Juan González-Lagoa characterized as Puerto Rico's geographical isolation. After several years of operation, however, interest in the program increased in the community and in the schools, and eventually the program began strongly influencing the school system curriculum. Dr. González reported that several students who were involved with the outreach program have gone on to continue their studies at institutions in Puerto Rico and mainland United States.

In recent years, the Mayaguez Campus has been shifting its academic focus from that of a traditional teaching institution to one more research oriented. Both perspectives are brought to the campus's Science on Wheels outreach program, which exposes teachers and students in remote areas to simple laboratory materials and equipment. The specific objectives of Science on Wheels are to motivate student enrollment in science, integrate student and faculty development, and make equipment available to junior and senior high school students for hands-on experiences with science.

Using a specially outfitted van, university faculty and students travel to local schools to make scientific presentations that are designed to be both interesting and exciting, and comprehensive enough to serve for teacher training in science education. For example, the unit on colors and light is used to teach conductivity, and the unit on fire teaches about combustion. From August 1992 to May 1993, the program reached over 2,000 students and over 150 teachers. In the spring of 1994, the program was extended to the Virgin Islands.

Educational technology takes many forms, from a traveling laboratory to computer simulations of molecules, explain Drs. Juan González-Lagoa and Juan López Garriga from the University of Puerto Rico, Mayagüez Campus.

Harvard University. Dr. Stephen Harrison described his experience in using interactive computer graphics to teach the structure of macromolecules and the relationships between structure and function. The graphics were used at different instructional levels: advanced projects and courses for juniors, seniors, and first-year graduate students; introductory projects in first-year organic chemistry; and a summer workshop for high school teachers. The university's chemistry department has several Silicon Graphics workstations that are available for science instruction. The workstations use a variety of standard software packages, most notably Quanta and HyperChem.

Introduction to Chemical Biology makes extensive use of the facility to provide instruction on a variety of biological questions, with emphasis on macromolecular recognition. The course units use the computer graphics in their problem sets, first teaching about the structure and typography of proteins, then moving on to more research-oriented exercises. The graphics are also used in a project format at the end of the first semester of the introductory sequence in organic chemistry. Students are encouraged to do research, then use computer graphics to illustrate some important properties of the molecules they are studying. This approach is effective for teaching about the complexities of molecular structure and the interface between macromolecular structure and chemistry.

The facility was also used in a summer workshop for high school teachers, who were able to learn about the structure of DNA. Dr. Harrison described enthusiastic feedback from the teachers. He encourages them to use computer graphics in a readily accessible form—mainly the Kinemage supplements to several standard textbooks that allow simple representations of macromolecular structures, using a desktop computer.

Beloit College. Beloit College has been at the forefront in developing computer-assisted materials for teaching biology and is the home of the BioQUEST Curriculum Consortium, which offers 28 computer-assisted instructional modules in a variety of scientific areas. QUEST stands for "quality undergraduate educational simulations and tools." Several elements in the curriculum's underlying philosophy are reflected in the development and use of the modules, according to Dr. John Jungck. One tenet is that the technology is a supplement to, not a substitute for, laboratory instruction, with the hope of providing "leading edge pedagogy and trailing edge technology."

The curriculum also focuses on "what we don't know." As Dr. Jungck explained, that approach is more likely to lead to discovery and problem solving than will the mere mastering of an existing body of knowledge for the purpose of answering questions in the back of a workbook. Dr. Jungck described it as focusing on "chaos and error rather than control and mastery." The approach is designed to prepare students to respond effectively to experimental error by reworking their models in a manner reflecting that of a scientist.

A final BioQUEST principle is to focus on learning rather than instruction, which according to Dr. Jungck involves a fundamental commitment to catalyzing students' enthusiasm for entering into the scientific community, in which they feel they are full participants. In keeping with this, the curriculum requires a shift in the role of the teacher, from being the "sage on the stage" or the "guide on the side" to a research collaborator, working in much the same way as a Ph.D. mentor.

One concept being advanced by Dr. Jungck is that educators should establish a system of peer review, in which users become field testers whose experience informs others trying to develop or adapt a computer-based program for their own use. He described what appeared to be a ready-made peer review community associated with BioQUEST. It consisted of BioQUEST staff, advisory board members, and oversight agencies at the core; a regional network of programmers, teachers, designers, and researchers with the fundamental underlying conceptual theoretical models; experienced users of existing technologies; and 3,000 subscribers to BioQUEST News.

The curriculum modules were designed with the student as an investigator and part of a team operating at the center of a learning environment. The team approach mirrors the reality of science, both in terms of how work is done and its peer review component. The students learn science by identifying and solving problems, and persuading other students about the validity of the data. Dr. Jungck emphasized the importance placed in the program on enhancing students' skills for communicating hypotheses, experimental design, and research findings. He practices what he preaches in his own classroom, where he has given up some lecture sessions in

Dr. Stephen C. Harrison and Scot A. Wolfe of Harvard University, and Dr. John Jungck of Beloit College discuss the impact of educational technology on teaching.

exchange for others in which student poster projects are peer-reviewed by student colleagues.

On a related point, Dr. Jungck urged HHMI to facilitate more extensive sharing of isolated developments in educational technology at individual campuses, to establish better connections among developers. One strategy would be to sponsor workshops for those who design curricula to critique and share ideas with one another. He also emphasized the importance of involving teachers and students in the design stage of educational technology in collaboration with the developer.

Discussion

The Economic Issues of Educational Technology. Educational technologies were characterized as broad-based tools. One member observed that educational software is widely used at her institution, and that students in the calculus sections that are completely taught with Mathematica are doing better than in previous years. The program is integrated into engineering and physics. Other audience members described successful experiences with various technologies, including one who indicated he had used Mathematica as the basis for a course for 200 students, and had used the genetics module from BioQUEST and Kinemage for its three-dimensional treatment of subjects.

A substantial part of the audience discussion was on the economic issues associated with using educational technology. Many audience members expressed concern over the cost of software licenses, and their comments indicated that choosing the right software involves not only content but also price. It

Dr. Stephen C. Harrison of Harvard University, also an HHMI Investigator, gives a demonstration of his macromolecular modeling program.

was observed that the price of site licenses goes down as a program becomes more widely used in an institution.

Another point raised during the discussion was that one often needs only part of a particular software but is required to buy the entire package. The irony of the disparity in cost between game technology and educational technology was also noted.

One audience member expressed her concern that the costs of hardware might be an issue where large numbers of students are involved. Dr. Harrison predicted that those costs will come down rapidly and added that one strategy for holding down cost is to make the computers available on a 24-hour basis. Wiring classrooms for multimedia presentations also involves substantial costs. A show of hands indicated that most institutions have their classrooms wired for computer hookups, but not for multimedia.

Ensuring the Participation of Women and Minorities. Issues of how people relate to computers were also discussed. Several audience members indicated a need for special efforts to make the technology available to women and minority groups, possibly even gender separation in the laboratory sessions, while others disputed the claim that women in particular are reluctant to use computers. Dr. Orville Chapman recommended a book, *Computers in Education*, that explores this and related issues in detail.

Dr. Jungck noted the role of computer-assisted instruction in curricular reform, saying that it parallels the trend in reform of moving from lectures toward workshops and more student-centered, application-oriented activities. He also indicated that computer-based instruction is particularly useful for classes involving interdisciplinary or intercurricular approaches, and that the team approach benefits both women and minorities.

A Note of Caution. The session ended with an impromptu recital of a poem written by New Orleans poet Maxine Cassin, entitled "In Appreciation of Stars." It was presented as a cautionary note that educational technology should enhance but never substitute for good teaching.

Educational Technology Demonstrations

Several computer-based educational technologies were demonstrated at the program directors meeting. The following descriptions of the various technologies were provided by the individuals listed at the end of each section. Please contact them for further information.

The BioQUEST Curriculum Consortium

Beloit College

The BioQUEST Curriculum Consortium develops software for open-ended problem solving in a variety of biological arenas. One of the recent pushes in biological education has concerned the development of quantitative and formal mathematical reasoning in biology. Mathematical models have been a rich source for the basis of a vast array of diverse computer simulations. These simulations offer many opportunities to explore enormous combinatorial complexity, to generate massive amounts of data for analysis, and to develop multiple visualizations of relationships between numerous variables. Among other things, the simulations can be used to illustrate the distinctions between discrete and continuous, deterministic and stochastic, and event- and time-driven models. Other approaches to mathematical reasoning in developmental biology employ digital videomicroscopy, computational geometry, and fractal analysis of morphology. A "strategic simulation" on pattern formation in developmental biology was being devised at the time of the program directors meeting.

John R. Jungck, Ph.D.
Professor and Chairperson
Department of Biology
Beloit College
700 College Street
Beloit, WI 53511
(608) 363-2267 or 2226
(608) 363-2052 fax

NeuroSim and NetSim

Case Western Reserve University

NeuroSim allows students to explore the effects of the morphology of nerve cells on their computational properties. Using a graphical interface, students can construct a complex branched neuron and, by setting parameters in dialog boxes, they can specify whether each part of this branched cable is passive or active. They can then graph different parts of the neuron's electrical properties as they inject currents into it. NetSim also allows students to look at simple neural networks of modified integrate and fire neurons. They can specify connections between model neurons, intrinsic currents, and synaptic properties, and then graph the activity of different parts of the network as currents are injected into it.

Hillel J. Chiel, Ph.D.
Associate Professor of Biology and Neurosciences
Department of Biology
Case Western Reserve University
2080 Adelbert Road
Cleveland, OH 44106
(216) 368-3846
(216) 368-4672 fax

Project LearnLink @ Emory University

Emory University

Project LearnLink is a computer bulletin board oriented toward building a community of learners in Emory classes and between Emory and other college and precollege educators. Employing an easy-to-learn interface based on the Macintosh and Windows point-and-click style of interaction, the system is widely used across Emory's campus in Atlanta. Through the use of Emory's network and modem pools, this system provides a service that has become a staple in many classes covering several different disciplines. Professors have reported that their students are challenged and entertained by the system. Some professors have given assignments, had students turn in papers, given extra-credit questions, and even held office hours via LearnLink.

Project LearnLink includes an outreach program for primary and secondary school educators and students and in many cases allows teachers to make use of resources that may already be available in their computer labs for little or no cost. The LearnLink Network, a collection of 150–200 primary, secondary, and university-level institutions, reached approximately 10,000–15,000 students in its first year. The network provides access to scientists from Emory (via the Ask a Scientist conference) and gives teachers opportunities to learn about different teaching styles and new uses of educational technology. Emory plans to expand the LearnLink Network to include associations of colleges and universities and other precollege educators.

Patricia A. Marsteller, Ph.D.
Director, Hughes Programs in Biology
Department of Biology
Emory University
1510 Clifton Road, N.E.
Atlanta, GA 30322
(404) 727-4272
(404) 727-2880 fax

Macromolecular Modeling

Harvard University

Professor Stephen C. Harrison, a Howard Hughes Medical Institute Investigator and a Research Associate in Medicine at the Children's Hospital in Boston, has developed a way to use x-ray crystallography to yield images of viruses in atomic detail. He employs this approach in studies of the organization of virus particles to investigate viral assembly and intracellular localization as well as viral pathogenesis. Dr. Harrison's research team has been using computer graphics to model macromolecules and their interactions in three different instructional contexts: (1) advanced projects in courses for juniors, seniors, and graduate students; (2) introductory projects in the first-year organic chemistry sequence; and (3) a summer workshop for high school teachers.

Stephen C. Harrison, Ph.D.
HHMI Investigator
Professor of Molecular and Cellular Biology
Department of Molecular and Cellular Biology
Harvard University
7 Divinity Avenue
Cambridge, MA 02138
(617) 495-4106
(617) 495-9131 fax

Scot A. Wolfe
Department of Chemistry
Verdine Lab
Harvard University
14 Boston Street, #3B
Somerville, MA 02143
(617) 496-5073
(617) 495-8755 fax

Magnification Concepts: The Use of Video-Probe Microscopy in the Introductory Biology Laboratory and for Kindergarten–12 Outreach

Louisiana State University and Agricultural & Mechanical College

The College of Basic Sciences and the College of Education at Louisiana State University have begun incorporating video-probe microscopy into their introductory biology laboratories. The hand-held probe can function both as a compound and a dissecting microscope. It provides instant, in-focus, real-time video images up to magnifications of 400× that are visible to all students simultaneously. This technology has also been effectively used in investigative laboratories, allowing students to examine structural problems and relationships without having to learn microtechnique processing procedures. Some types of studies are *in situ* pollen tube growth, structure/function conditions in wood, *in situ* cell growth kinetics, examination of callus growth in tissue culture, and plankton sampling for ecological studies.

Following exposure to successful video-probe studies, students show increased desire to master conventional microscopy. In kindergarten–12 classrooms, extremely enthusiastic students examine samples ranging from their own fingerprints and clothing to pond water, prepared microscope slides, and microscopic light-polarizing phenomena. Teachers at all levels report unqualified success with classroom use of the video probe and note that students show increased interest in scientific observation once the "video connection" has been made.

Harold Silverman, Ph.D.
Associate Dean
College of Basic Sciences
Professor of Zoology and Physiology
Louisiana State University
and A&M College
338 Choppin Hall
Baton Rouge, LA 70803
(504) 388–8859
(504) 388–8826 fax

Cindy Henk
Research Associate
Department of Microbiology
Louisiana State University
and A&M College
508 Life Sciences Building
Baton Rouge, LA 70803
(504) [illegible]5–8860
(504) 388–2597 fax

Interactive Lab Manual for Biochemical Techniques

University of California–San Diego

A collaborative effort at UCSD has produced an Interactive Laboratory Manual, a modular, Macintosh-based, highly interactive multimedia software product. It gives students the opportunity to prepare for an actual wet laboratory—Biochemical Techniques—by reviewing an experiment, learning more about the main technique being used, practicing math skills that need to be applied in the lab, and refreshing or acquiring the necessary background information.

Screen features and overall layout were carefully designed, taking into account pedagogical and cognitive implications of the learning process. On-screen information is presented to the students in a nonlinear fashion; and numerous branching points, layers, and "food-for-thought questions" allow them to become actively involved in a discovery process. Photos, movies, illustrations, and animation help students to visualize experimental steps and equipment setup as well as events happening on the molecular level. Simulations allow students to practice with the equipment. A system is built into the modules that allows electronic communication between an instructor and students, as well as online searching of the library. Using the Interactive Laboratory Manual, students can prepare at their own speed and to the depth they choose.

Barbara Sawrey, Ph.D.
Tenured Lecturer and Academic Coordinator
Department of Chemistry
University of California–San Diego
9500 Gilman Drive, 0303
La Jolla, CA 92093–0303
(619) 534–6479
(619) 534–7687 fax

Gabriele Wienhausen, Ph.D.
Tenured Lecturer and Academic Coordinator
Department of Biology
University of California–San Diego
9500 Gilman Drive, 0355
La Jolla, CA 92093–0355
(619) 534–3018
(619) 534–1835 fax

Mathematica

University of Illinois at Urbana–Champaign

In using computers in a classroom setting, a primary consideration is what the computer approach will offer in comparison with the traditional classroom format. The role of the computer can be simply to augment regular course work by automating certain tasks. However, taking full advantage of the capabilities of computers requires replacing traditional teaching approaches. This has been done in adapting Calculus&*Mathematica* for teaching introductory calculus to our life sciences majors in a course titled BioCalc.

Originally developed jointly with William Davis from Ohio State University for teaching math to engineering students, Calculus&*Mathematica* uses computers as the primary means for teaching and learning. There are no textbooks, calculators, or scratch pads. Rather, students do lessons in notebook form on Macintosh or PC computers, with each lesson consisting of three sections: Basics, Tutorials, and "Give It a Try." BioCalc, by emphasizing the visual acquisition of information rather than traditional computational exercises, and using relevant problem sets derived from real-life situations, takes advantage of the strengths of life sciences students while also clearly demonstrating the relevance of the mathematics to the students' own interests in life sciences. Undergraduate freshmen, including potentially "at-risk" students, succeed and thrive in this environment, developing an intuitive understanding of calculus and mastering even advanced differential equations. Student response and performance have been overwhelmingly positive, with 90 percent of students receiving an A or B in BioCalc.

Sondra G. Lazarowitz, Ph.D.
Associate Professor and Program Director
Department of Microbiology
University of Illinois at Urbana-Champaign
131 Burrill Hall
407 South Goodwin Avenue
Urbana, IL 61801
(217) 333–0390
(217) 244–6697 fax

Claudia Washburn
Program Manager
School of Life Sciences
University of Illinois at Urbana–Champaign
390 Morrill Hall
505 South Goodwin Avenue
Urbana, IL 61801
(217) 333–7903
(217) 244–1224 fax

Electronic (Multimedia) Theatre Used for Teaching and Presentations

Wofford College

The "teaching theater" is a classroom equipped with projection television that has computer graphics and other presentation capabilities. One important use of the classroom is to teach computer applications to students and permit them to make presentations to the entire group about what they have learned and are learning. The classroom also has cable, electronically indexed videotape, videodisc, video copystand, slide, slide-video transfer, telephone, and computer network capabilities. The classroom empowers presenters and gives them great flexibility to explore information in its many and varied forms.

B.G. Stephens, Ph.D.
Vice President
Wofford College
429 North Church Street
Spartanburg, SC 29303-3663
(803) 597-4294
(803) 597-4549 fax

Overview of Assessment Strategies

University of Arizona ■ Michael A. Wells, Ph.D., Carol Bender, M.S.S.S.
University of California–San Diego ■ Gabriele Wienhausen, Ph.D., Barbara Sawrey, Ph.D.
Wellesley College ■ Mary Mennes Allen, Ph.D., R. Steven Schiavo, Ph.D.

Dr. Michael Wells of the University of Arizona presented several strategies used to evaluate the student research program at his institution. Dr. Gabriele Wienhausen of the University of California–San Diego discussed the importance of using a professional evaluator and starting to collect data at the beginning of a program. Dr. Mary Allen described the extensive data sources for assessment of science students at Wellesley College. In the discussion period, participants focused on the difficulty of defining program success, the importance of credible evaluations, the validity of control groups, and whether students' grade point averages can predict their success in laboratory research.

Presentations

University of Arizona. The HHMI-supported Undergraduate Biological Research Program at the University of Arizona employs four different assessment strategies, Dr. Wells said: evaluations, questionnaires, follow-up, and collection of anecdotal information from students.

Demand for a program among students and faculty can provide one measure of the program's usefulness, Dr. Wells said. When the HHMI program started in 1988, only 19 students applied and just 13 faculty agreed to sponsor students in their laboratories. Six years later the number of applicants reached 258, and the number of potential faculty sponsors stood at 205. According to Dr. Wells, these two indicators suggested, from the perspective of faculty and students, that the program was beneficial.

The program also uses questionnaires at the end of the summer and the academic year to measure satisfaction with the research experience among participating students and their faculty sponsors. For example, using a five-point scale, students rate the research project in terms of meeting their expectations and its effectiveness in teaching biology. Students also describe the project and goals and provide other information. Faculty use a similar system to rate student performance and learning; they too describe the project and answer whether they want to continue in the program.

The most difficult part of any assessment Dr. Wells said, is following up on the program's long-term impact and tracking students who have participated. To that end, the University developed a database for collecting each student's local address,

84

Dr. Gabriele Wienhausen, University of California–San Diego, stresses the importance of planning in assessment. She is joined by Drs. Barbara Sawrey, also of UC–San Diego; Mary Mennes Allen and R. Steven Schiavo of Wellesley College; and Ms. Carol Bender and Dr. Michael A. Wells of the University of Arizona.

the parents' address, lists of programs the student has been in, research sponsor, funding source, student and faculty evaluations, and other information. Of the 269 undergraduate biological research students who have graduated to date, 85 have gone on to medical school and 71 to graduate school. Estimates based on prior experience suggest that without the program, only 12 would have gone to graduate school.

Students receive a monthly newsletter, participate in an annual poster session, and organize picnics, seminars, and field trips. Dr. Wells said these activities help them to identify with the program and encourage cooperation in the university's assessment and tracking efforts. Anecdotal comments are also used in evaluating the program.

University of California–San Diego. At the University of California–San Diego, an HHMI grant supports an outreach program to local middle and high schools, and an undergraduate program that supports 100 new science students each year, said Dr. Wienhausen. Students applying to the undergraduate program are divided into three groups—underrepresented minorities, women, and others. One-third of the program participants are randomly selected from each group, and unselected applicants serve as a control.

The goals of the program, she said, are to encourage students to stay in science, succeed in getting into graduate or medical school, and maintain the grades that will allow this to happen. The assessment is designed to determine whether these goals are achieved and to feed the results back into program development. The assessment allows directors to fine-tune the mechanisms of the program and develop a stronger commitment to it among the students.

Dr. Wienhausen said that students help evaluate the program, thereby gaining a sense that they can actively modify it. Assessment results indicate that the HHMI participants remain in science, she said. The dropout rate among science majors in the program is low, and the dropout rate from the university is even lower.

One key to successful assessment is to bring in a professional evaluator trained in the social sciences, Dr. Wienhausen said. Another is to establish a database at the outset and collect sufficient data. The evaluator helped the program's coordinators clarify goals and directives and determined what data to collect. For example, data were gathered on the extent to which students participated in program activities. It turned out to be informative to compare the more active with the less active students, and compare these groups separately against the control group. That meant collecting data on how often the HHMI students actually participated in program activities.

The evaluator also pointed out that simply comparing grade point averages of HHMI participants and the control group might be misleading. Since the program is aimed at keeping low-GPA students from dropping out, a successful effort would result in a lower average GPA for HHMI participants compared with that of the control group, whose average GPA would increase as low-GPA students dropped out of the university.

According to Dr. Wienhausen, these examples illustrate the importance of collecting large amounts of data in conducting program assessments. She also noted the utility of designing a database that allows easy storage and retrieval, suggesting the value of a professional evaluator.

Wellesley College. At Wellesley College, a liberal arts women's institution, several activities in addition to HHMI-funded efforts have been undertaken to collect data and assess students in science, Dr. Allen said. Many data on student outcomes are gathered from the premedical adviser's office and the academic departments. Data are also collected from questionnaires given to students and faculty. Other information is obtained from focus groups, students, faculty, and alumnae, and from exit surveys completed by graduating students. A "data warehouse" will be used to store students' backgrounds, SAT scores, course grades, professors, etc.

Wellesley College has also initiated two major assessments of science students. Pathways for Women in Science is a longitudinal study of the 538 members of the class of 1994, designed to explore the factors involved in women's decisions to pursue science as an area of study or as a career. The women were questioned upon registering, completing their first science course, selecting a major, and graduating. They are also being tracked after college.

The college has also surveyed about 2,500 graduates from 1983 to 1991 and is extending the study to include graduates back to 1968, Dr. Allen said. About 40 percent of the 1983–1991 graduates were science majors. Of those, 64 percent remained in science, and the remaining 36 percent changed to another field. Three-fourths of those who changed did not go on to graduate school or medical school. "Retention over time was something we thought would happen, but in fact, did not take place."

The survey also revealed that for science students who did go into graduate or medical school, three factors were important in their undergraduate experience: mentoring, research, and encouragement from advisers.

The assessment efforts at Wellesley College have also identified several needs for the science departments to address. For example, when the Pathways study indicated student dislike for lectures, the introductory biology course for 200 students was split into sections of no more than 36. But student questionnaires now reveal a new concern. As Dr. Allen notes, the particular instructor to whom a student is assigned is a very important factor in her decision to pursue science.

The issue of defining success in terms of the HHMI program was also addressed. For example, is retention of students in science after graduation the goal of the program? Or might the development of scientifically literate citizens also be included? Also, how can adequate control groups be structured? For example, the college's new mentoring program for underrepresented minorities selected students without research experience. But having a control group became unfeasible when it turned out that most of the nonselected students had had other research experience.

The timing of assessments has also proved to be critical, Dr. Allen said, because many students work for a time after graduation and then go on to graduate or medical school. An assessment of 1989 graduates three years after leaving college found that 41 percent were in medical or graduate school. A survey two years later revealed that the number had risen to 82 percent.

Discussion

Broadening the Definition of Success. Defining the meaning of success in science education programs was a concern to many participants. Dr. Steven Zottoli of Williams College cautioned against equating success strictly with retention of students in medical or graduate school. Some programs may strive to increase the scientific literacy of the general population, and that goal needs to be considered in assessments.

A broader definition of success was proposed by Dr. Mark Dubin of the University of Colorado at Boulder, who suggested that science education programs might be considered successful when they help students decide not to pursue a scientific career.

Others voiced similar opinions, especially about the success of undergraduate research in helping students decide for or against a life in the laboratory. Dr. Wells said that the experience can give students the opportunity to sample a research career in a manner that is relatively inexpensive for them. If students attend graduate school and then find it is not the right choice, they have invested time and money that could have been directed elsewhere. That view, however, prompted Dr. Clifton Poodry of the National Institutes of Health to ask whether underrepresented minorities were perhaps being counseled to leave science rather than stick it out, and cautioned the attendees to consider the advice carefully, given the strong incentive to retain minority students in science.

For these and other reasons, surveying students who leave science after graduation or later change careers is important, participants said. Assessment work at Wellesley College, said Dr. Steven Schiavo, has found that one graduate may go on in science while another with the same academic record does not.

Is an External Evaluator Necessary? Some participants agreed that it is important to get professional outside evaluators to assess programs. At the University of Michigan, the independent Center of Research and Learning on campus was contracted to evaluate a calculus reform project that was being scaled up from a successful pilot study to a large, expensive program. "We, the dean's office, simply weren't going to buy into this unless we had a credible evaluation procedure," said Dr. Michael Martin. The center is performing a credible evaluation, he said, and "the data that are coming in are believed by both the math department and the dean's office." At the University of Wisconsin, the LEAD (learning through evaluation, assessment, and dissemination) Center evaluates new programs, including the HHMI-funded effort, said Dr. Paul Williams.

Finding Valid Controls. Some participants discussed the validity of control groups, especially in light of the tendency toward self-selection by students applying for HHMI programs. One participant—noting that only those students who were highly active in the HHMI program at the University of California–San Diego were considered in the comparison that showed program benefit—questioned whether the use of a control group was appropriate. Dr. Barbara Sawrey of the University of California–San Diego said that control subjects were drawn from a pool of about 800 unsuccessful program applicants and were matched as closely as possible to the program participants

Who Benefits Most from Research Experience? On another issue, participants discussed how student grade-point averages might correlate with research success. Dr. Wells said that he has observed no correlation between laboratory research performance and GPA once a student has passed a 3.0 average. Above that level, motivation and other factors seem more important to success in the laboratory. He noted, however, that students whose GPAs are below 3.0 tend not to perform as well.

Dr. Sawrey agreed but argued that an experience in a research laboratory might be the factor that motivates a student with a 2.75 or a 2.5 GPA to succeed in college and beyond. She emphasized the importance of finding the most appropriate laboratory setting for students, particularly those who have not performed as well in college as other students.

Care should be followed in placing students at high academic risk in a laboratory, said Carol Bender of the University of Arizona. If students are doing poorly, she noted, spending time in a laboratory rather than on course work might exacerbate the problem.

Student Tracking in Research and Prefreshman Programs

Tuskegee University ■ J.H.M. Henderson, Ph.D.
University of Michigan–Ann Arbor ■ Sandra Gregerman, M.S., Michael M. Martin, Ph.D.
Williams College ■ Steven J. Zottoli, Ph.D., Daniel V. Lynch, Ph.D.

Dr. J.H.M. Henderson described Tuskegee University's prefreshman program and its method of tracking students. Sandra Gregerman presented the extensive effort under way to evaluate the University of Michigan's undergraduate research program. Dr. Steven Zottoli explained how tracking a select group of precollege summer science students at Williams College has revealed strengths and limitations of the HHMI-funded program. In the discussion period that followed, participants discussed at length the merits of various program selection approaches. They also discussed the need for positive role models for women and minority students and the difficulties of establishing adequate control groups for assessment.

Presentations

Tuskegee University. The HHMI-funded prefreshman program at Tuskegee University brings about 20 high school graduates from across the country to the campus each summer for a program designed to encourage them to pursue college-level science. It selects from students who have a 3.0 or higher grade point average, have scored 1,000 or higher on the SAT test, and have expressed an interest in biology or chemistry.

To encourage summer students to remain at the university, the program offers financial support for the first two years and the possibility of additional support during the second two years through NIH's MARC, MBRS, or other programs. Dr. Henderson noted that the program has been more successful in recruiting females than males, who have accounted for only 20 percent of the summer students. Tuskegee will continue its efforts to attract black males, a group particularly underrepresented in the sciences.

The prefreshman program has tracked students who attended the science program in the summers of 1989 through 1992, using questionnaires and follow-up telephone calls to students' parents. A total of 77 students attended during that time, and 67 have been successfully tracked, Dr. Henderson said. A total of 30 students remained at Tuskegee, and 37 went on to other institutions.

University of Michigan. The University of Michigan is conducting a four-pronged evaluation of the Undergraduate Research Opportunity program, said Sandra Gregerman. HHMI funding, which began in 1992, helped expand the program and

Techniques for tracking students is the topic for Drs. J. H. M. Henderson of Tuskegee University, Steven J. Zottoli of Williams College, and Ms. Sandra Gregerman of the University of Michigan–Ann Arbor.

increased the number of biomedical research placements by 50 percent of the total.

The program aims to improve the retention and academic performance of minority students by engaging them in research, especially in the freshman and sophomore years, Ms. Gregerman said. Participants work as research assistants for 6 to 15 hours per week, receive peer advising, and participate in peer groups that meet semimonthly to discuss research ideas, explore career opportunities, and talk about other common issues. The program began in 1989 with 14 students and had 750 in 1994, with 45 percent being underrepresented minority students. About 16 percent of the students on campus are minority students.

The evaluation design includes several survey instruments and a longitudinal analysis of three cohorts of program participants, she said. Students take a detailed pretest upon entering the program and a posttest after one year. Study subjects are selected randomly and compared with a control group of students—matched for grade point average, standardized test scores, and type of high school—who applied to the program, but did not enter.

One prong of the evaluation investigates academic measures such as retention rates, grade point averages, and course selection patterns. "We're looking at whether or not participating in the program actually encourages students to take more rigorous academic course loads, to increase the number of credit hours that they take, to begin earlier on their academic careers, or to take more upper-level courses," Ms. Gregerman explained. Initial results indicate that retention of the program's participants is 50 percent greater than that of students in the control group.

A second prong explores psychosocial variables. To what extent do students participate in the program or in other academic and social activities? How does program participation affect students' self-concept, expectations, social network, and feelings of well-being on campus? According to Ms. Gregerman, one of the reasons women and minority students often do not achieve as well as majority students is that they do not identify with the university, and tend to separate their academic and social lives. The program attempts to address these obstacles by offering students a range of activities that connect study and socializing.

A third prong of the evaluation examines which components of the program are responsible for higher retention rates and other successes, she said. Is program participation more helpful in the freshman or sophomore year? Is the program more beneficial to students entering with a low or a high grade point average? If retention rates are up, is that because the program has helped students feel better about the university or because it has helped them find more positive ways to cope with classroom pressures?

A fourth prong of the evaluation looks at the program's impact on the faculty. Understanding faculty attitudes is difficult, Ms. Gregerman said, but faculty are asked in a detailed survey whether or not participation in this program has made them more interested in teaching and the success of their students. The survey also examines the extent to which programs such as this help shape faculty teaching of women and minority students.

Williams College. At Williams College, assessment of the HHMI-funded program began with an effort to separate program effects on biology enrollments from broader local and national effects, Dr. Zottoli said. The national economic climate is apparently boosting the number of students heading for medical school. The availability of external funding, such as the HHMI grant, also affects enrollments. In addition, increases in the number of women faculty are attracting more female students to the discipline. At Williams, about half ot the biology faculty are now women.

Data on Williams College since 1990 indicate that biology enrollments have increased, retention has risen substantially across the various sciences, and underrepresented minorities have contributed to the increase in science majors, Dr. Zottoli said. These findings suggest that the HHMI program is having a positive effect in addition to that of other factors.

Program coordinators began tracking students in the Summer Science component as a means of discovering the aspects of the program that are strong and those needing improvement, he said. Each summer the program selects 12 to 14 high school students who will enroll at the college in the fall. The idea is to give them early exposure to the institution and some of the science they will encounter, thereby drawing students into the introductory science curriculum. Other major components of the HHMI program at Williams College include a resource center that offers tutoring to support the introductory science curriculum, and research opportunities for upper-level students.

Selection of the Summer Science students presents some assessment problems, he said. The sample is small, and an appropriate control group may not always be available, but the process is valuable because it reveals science enrollment and other trends. The students are being tracked through college, will be interviewed when they graduate, and will be followed thereafter. Early results indicate that increasing numbers of these students are being retained in science majors.

Program coordinators had anticipated that high percentages of Summer Science students would enter the introductory science curriculum and use the resource center. They were surprised, Dr. Zottoli said, to see signs of even stronger participation in the HHMI program, with 41 percent of the students that used the resource center in 1994 having been participants in the Summer Science program.

The assessment has also revealed a need, he said, to increase recruitment of the Summer Science students into the next level—the research phase. Though over 25 percent of the Summer Science students have gone on to enter the research program, he believes that the figure could be improved with additional advertising.

Discussion

The Student Selection Dilemma. Participants spent much of the period discussing how students are selected for research and other science education programs. Some programs select the best-prepared students and others the least prepared, and many programs favor students with little or no research experience. The discussion raised questions of developing assessment goals and approaches appropriate to program goals.

At Wellesley College, many students apply for a limited number of HHMI-funded laboratory opportunities, and the faculty selection committee tends to pick students with higher grade point averages, said Dr. Mary Allen.

Dr. Steven Kolmes of Hobart and William Smith Colleges drew a distinction between programs that select students with high grade point averages and programs, such as his, that recruit students with low averages. He said that students who complete the Hobart and William Smith College program have a higher retention and graduation rate than the general student body. He suggested that the benefit-to-cost ratio of such programs is high.

At the University of Michigan, the program admits students regardless of grade point average, Ms. Gregerman said. But it may change its selection procedure as it gains experience with students that score low. Preliminary results indicate that program participants entering with high GPAs are retained at slightly higher rates than the control group. Those entering with low GPAs, however, are being retained at dramatically higher levels than the control group.

Several participants suggested that providing opportunities for students without research experience is an appropriate goal. Selection committees for research-related programs are tending to select students with no research experience over those who already have it, say program directors from Wellesley College, Johns Hopkins University, and the University of Illinois at Urbana–Champaign.

At Arizona State University, program coordinators select one group of students with high GPAs and another group who appear to be at risk, Dr. James Collins said. Both are now being tracked. The program at the University of Colorado at Boulder offered two research programs, one at the entry level aimed at highly motivated students with no research experience and the other at an advanced, competitive level where entry is based on the merit of the student's research proposal, said Julie Graf.

According to Ms. Graf, the university found that many women and students of color were not taking advantage of the research program because they may have felt they lacked the research skills, science training, and contacts of other students. Students who succeed in the entry-level program are encouraged to apply for the more advanced research.

Data from the University of Michigan suggest that a sequential approach to research experience is beginning to work. Many of the program's participants go on to other programs at the university, Ms. Gregerman said, and they are selected at a much higher rate than students who did not have the experience.

Program coordinators at the University of Illinois found that changing the application procedure had a dramatic effect on applicants to the program, said Claudia Washburn. The original process required students to identify a faculty mentor willing to work with the student and to write a research proposal. The students who applied to the program tended to be those already established in a laboratory and with clear-cut career plans. Program coordinators then changed the application process, requiring only completion of a simple application form and a written personal statement, she said. Applicants were not required to have a faculty sponsor, a letter of recommendation, or a research proposal. The new procedure increased the numbers of applicants and participants. Applications from women and underrepresented minorities have increased, she said.

Positive Role Models for Women and Minorities. Participants in the discussion pointed out that students, including women and minority students, need positive role models who will foster their interest in science. Dr. Henderson described the experience of a student at his institution who was discouraged from pursuing science by a faculty member. A key to successful programs, discussants said, was to involve faculty members who are positive about their teaching and working with students.

According to discussants, a way needs to be found to institutionalize the roles of those persons good at "academic matchmaking" between professors and students. Ms. Gregerman emphasized, however, that faculty who are reluctant to work with women and minorities should not be let off the hook. She recommended involving as many faculty members as possible in such programs, noting that the burden of responsibility would otherwise fall on relatively few. In addition, she noted that faculty also benefit from working with students from a range of backgrounds.

Valid Controls in Assessment. Participants commented on the difficulty of finding adequate control groups for their assessments. Drs. Zottoli and Allen said their colleges have too few minority students to form both a study and a control group. The control group established for the evaluation under way at the University of Michigan, Ms. Gregerman said, was based on random computer-generated samples.

Curricular Reform: How Well Is It Working?

Bates College ■ Martha A. Crunkleton, Ph.D., Pamela Baker, Ph.D.
Carnegie Mellon University ■ Susan A. Henry, Ph.D., William E. Brown, Ph.D.
University of California–Los Angeles ■ Frederick A. Eiserling, Ph.D., Orville Chapman, Ph.D.

The institutions represented on the panel range from liberal arts colleges to universities and are located in very different regions of the country. Each institution has had different experiences in curricular reform in science, which are summarized below.

Panel Presentations

Bates College. Since 1991 the faculty at Bates College, a liberal arts college in Maine, has been conducting an intensive review of the overall curriculum. During this process, the science faculty changed the core curricula in biology and other areas of science to emphasize investigative, collaborative learning and a hands-on laboratory approach. In the process, the core shifted from covering specific bodies of knowledge to the scientific process. Among other things, the shift in emphasis was seen as a way to attract and retain women and underrepresented minorities in the sciences.

In the biology department, introductory courses have become more investigative through the introduction of the principal investigator (PI) system, which was first used in Cell and Molecular Biology. Under the PI system, students develop an understanding of scientific methodology and critical thinking as well as skills in collaborative research. Writing skills also are emphasized in the core courses. Upper-division students serve as technical writing assistants for students preparing laboratory reports in introductory classes, and lab reports are written in the format of a scientific paper.

Although the number of students enrolling and majoring in biology has increased dramatically, only two years' worth of students have moved through the new biology core. Dr. Martha Crunkleton indicated that the test of the program will occur when these students enter advanced biology courses and demonstrate their skills. She also noted that the curricular reforms in science strengthen student performance by providing the underlying skills for independent research, an important aspect of the College's progr .n that has been expanded with HHMI support. Also with HHMI support, Bates College has launched a new biochemistry major, is developing additional biology courses, and is undertaking a complete laboratory revision of comput-

96

Drs. Martha Crunkleton, Bates College; Frederick A. Eiserling, University of California–Los Angeles; and Susan A. Henry, Carnegie Mellon University, respond to questions about comprehensive changes in their curricula and departmental structures.

er-aided instruction in introductory physics.

In closing, Dr. Crunkleton cited the following increases in enrollment, which she attributed at least in part to curricular reform. Before the revisions in Bio 101, the course usually enrolled about 90 students; this year, there were over 200. In 1990 Cell and Molecular Biology had 42 students; in 1994, more than 90. The impact is now reaching the advanced biology courses, as more students stay in the major. In Dr. Pamela Baker's immunology course, enrollment jumped from 4 students in 1989 to 30 in 1994. In 1992, there were less than a dozen chemistry majors; now there are 35 chemistry and biochemistry majors. In 1991, less than a dozen students conducted summer research with faculty members; in 1994, 63 students were research collaborators.

Carnegie Mellon University. Dr. Susan Henry noted that broad-based curriculum reforms were occurring at Carnegie Mellon University, which were preceded by changes in the advising program designed to introduce more flexibility and more choices for the student in the freshman year. As was the case at Bates College, the natural connection between research and curriculum is a cornerstone of the university's efforts to improve the undergraduate science curricula. There has been a significant increase in the number of new and retained science majors coinciding with the changes. However, this could also be attributed to another change—for the first time, the science department could recruit science majors at the freshman level.

Dr. William Brown reported that the number of undergraduate biology majors at the university doubled in the past three years, which has driven the curricular reform efforts toward developing an outlet for this enormous growth and at the same time expanding new frontiers in the field. One effort that HHMI is supporting is the development of an interdisciplinary program in computational biology. The university is assessing the computational biology curriculum not only on the basis of the quality of the instruction, but also by looking at the student demand for the major and the proliferation of related courses. Another measure of the success of the computational biology program, Dr. Brown reported, is that the approach has been "institutionalized," i.e., computational tracks have also been developed in chemistry, physics, and mathematics. Regarding the placement of undergraduate students in the laboratory during the period from 1988 to 1994, 77 percent of the 172 science graduates were involved in research. A significant fraction of them went on to pursue Ph.D.'s in science.

Drs. Pamela Baker of Bates College and Frederick A. Eiserling, University of California–Los Angeles, appear to agree with UCLA's Dr. Orville Chapman, who says that "assessment is the crabgrass in the academic lawn."

University of California–Los Angeles. Dr. Eiserling described several challenges for curriculum reform in life sciences at the University of California–Los Angeles. One major challenge is departmental resistance to change, which at UCLA is compounded by the structure of the departments in life sciences—five departments and 110 faculty—and the presence of multiple perspectives about what new directions should be taken. He indicated that department structure must be "loosened up" in order to accomplish academic change.

Initially, the impetus for curriculum reform at the university was primarily economic rather than pedagogic. Cutbacks in the number of faculty have raised questions of survival and have led to changes based on administrative efficiency. Previously, departments controlled graduate study in research, academic personnel, undergraduate curricula, and staff administration. Some of these responsibilities have been centralized for administrative purposes. However, the necessity for operational efficiency also was used as an opportunity to realign the sciences in keeping with current trends toward interdisciplinary collaboration. Barriers have dropped and departments are now sharing resources along the lines of current research interests rather than traditional disciplinary lines. For additional information on the subject, Dr. Eiserling recommended *The Predictable Failure of Educational Reform* by Seymour Sarason.

Dr. Orville Chapman described assessment as "the crabgrass in the academic lawn" because "we do it poorly; it's the worst thing we do." He described the assessment of an innovative computer-based course that was a great source of pride. But the first formal assessment of the program, conducted independently by cognitive scientists, yielded disappointing results. There was no difference between the course grades of students in the control group and those in the experimental group. Dr. Chapman sought an explanation from a cognitive psychologist, who noted that the computer laboratory—designed to improve students' understanding of the discipline—only tested for performance on rote learning and exercises, not understanding. This story illustrated the main point of Dr. Chapman's presentation, which was that more appropriate methods of assessing student learning and understanding are a prerequisite for achieving educational reform.

Discussion

An Assessment Dilemma: Ruling Out External Forces. One of the main issues that were brought up concerned assessing the impact of curricular reform on increasing enrollments *vis à vis* other influences, a variety of which were identified: cultural changes in society, aggressive admissions strategies, and shifts away from other fields—where prospects for employment are diminished—toward relatively secure fields, such as medicine, into which biology may feed. Increased enrollment in courses that have not been changed indicates that outside influences are probably at work. It was suggested that a more appropriate indicator for the impact of curricular reform would be whether there was a sustained interest in science, i.e., the retention of upper-division students who in their freshman year declared science as a major. A decrease in the number of science majors should prompt an examination of introductory courses and other early experiences (including advising) that may be discouraging students.

Institutional Commitment. There was a general sense that curricular reform cannot be done in isolation; it must be part of an overall change in the institution. One such change is that faculty should view helping to recruit, advise, and retain undergraduates in science as part of their core responsibility. One program participant commented that the current attitudes are reflected in the fact that faculty typically talk in terms of research *responsibilities* versus teaching *loads*. It was suggested that many faculty trained as researchers may need additional training and incentives in teaching. A variety of programs are in place at different institutions, ranging from one for excellence in teaching to one in which faculty participation affects salary increases, promotion, and tenure. One participant said his teaching was improved by enrolling in a music theory course, because confronting a completely unfamiliar subject area helped him understand what his students experience.

Using Reform to Influence Student Expectations. Another area of change is in student expectations about what they will be taught in science courses—e.g., the misconception that they are merely preparing for the GREs and MCATs. Different objectives and different learning styles must be recognized and accommodated in the curriculum reform process, and these should not be undercut by the need for assessment or the need to pass standardized tests for graduate or professional school.

The Role of Education. Discussion followed on the role of education departments in curricular reform and assessment. In many institutions, science departments have distanced themselves from colleges of education, and it was generally agreed that increased consultation should occur. The implications of curriculum reform also extend to in-service training of teachers in kindergarten–12, because changes must take place at the precollege level to prepare students for new approaches in higher education.

Assessing Outreach Programs

North Carolina State University ■ William C. Grant, Ph.D., Sarah Berenson, Ph.D.
University of Chicago ■ Robert L. Perlman, Ph.D., Anne M. Heinz, Ph.D.
Villanova University ■ R. William Marks, Ph.D., William M. Fleischman, Ph.D.

The panelists and their colleagues described three outreach programs that tak very different approaches to assessment. The North Carolina State University program targets rural high school science teachers, providing them with training and equipment. To assess how well the program is reaching its goals, the university's Center for Research in Mathematics and Science Education conducts an evaluation using a range of methods, including detailed questionnaires and sophisticated statistical analysis. The University of Chicago is reaching out to local high school science teachers through a series of summer seminars taught by university faculty. For the past three years, the program has employed an evaluator from the Graduate School of Public Policy Studies at the university who uses pre- and postseminar tests and follow-up questionnaires. The focus of Villanova University's program is high school juniors and seniors who attend a six-week summer program designed to help students with an aptitude for biology become more comfortable with and interested in mathematics. The program relies on an exit survey at the end of the summer session for program evaluation.

Presentations

North Carolina State University. According to Dr. Sarah Berenson, North Carolina State's year-round program targets rural high school teachers of chemistry, physics, and biology, encouraging them to adopt an interdisciplinary teaching approach to complement traditional practices. The program consists of three parts. In the first, teachers learn in summer workshops how to teach skills in science process, using computers and other laboratory equipment.

During the second part of the program, which consists of school site visits, the program staff take computers and other teaching tools to rural schools, help teachers become familiar with them, and leave them with the teachers for classroom use. During the third part, the rural teachers come to the North Carolina State campus to discuss their progress and any problems they are encountering in implementing the new teaching approach.

Dr. Berenson said that the primary goal of the university's program is to change the way teachers teach science. In particular, the program encourages them to rely more on laboratory and investigative approaches than on lectures; more on process skills than on memorization; more on technology than on

work with paper and pencil; and more on teacher questions than on supplying answers.

In assessing the effectiveness of the program, North Carolina State University has evaluated both the management of the program and its effects. To evaluate management, the university tries to answer a number of related questions: What are teachers' attitudes about the project's activities? What do they consider to be the strengths of the program? And what do they consider is needed to improve the program?

The university attempted to answer additional questions to evaluate the program. Do teachers use the knowledge they learned in the program and the materials they were provided? Do they develop new lessons that use technology? Are they using their newly gained knowledge with their colleagues? And are teachers taking the initiative to leverage additional resources from their administration to implement new approaches?

To answer these questions and arrive at an evaluation, North Carolina State University uses a mix of methods. These include teacher surveys composed of both quantitative measures (Likert scales and lists) and qualitative measures (open-ended questions). The program also uses teacher anecdotes, project records, and teacher interviews, including group discussions on videotapes.

Dr. Berenson presented a sample page of one of the question-

Dr. William M. Fleischmann, Villanova University (standing), makes a point about evaluating outreach programs. He is joined by Drs. Sarah Berenson of North Carolina State University, Robert L. Perlman and Anne M. Heinz of the University of Chicago, R. William Marks of Villanova, and William C. Grant of N.C. State.

naires to illustrate the multiple measures used. Teachers were asked to check off applications they used in their classrooms after they had received training through the program, such as the use of hands-on materials, the use of computers, and students working in small groups. They were also asked an open-ended question about what they had learned and were asked to compare their current teaching approach to their previous one, using a 1–to–7 scale.

Dr. Berenson's conclusion, based on the assessment to date, was that the teachers who had been in the program were beginning to change their teaching methods as a result.

The University of Chicago. Dr. Robert Perlman described the University of Chicago's summer seminar program fo high school teachers, which the university began a decade ago. Administered by the office of the university president, the program offers seminars by faculty in a variety of disciplines. HHMI grants currently support two seminars, and the university will soon be adding a third.

The science seminars are held three to five days a week for four or five weeks during the summer. They involve a total of 15 to 20 teachers each year, Dr. Perlman said.

The goals of the program have been evolving, according to Dr. Perlman. When the seminar program began, the goal was strictly to provide intellectual renewal for high school teachers, by bringing them up to date on the latest developments in their subject areas. Over time, the focus has shifted to pedagogical issues, with the goal of transforming teacher practices in the classroom.

Dr. Perlman added that the character of the seminars is very much determined by the interests of the faculty members who teach them. He gave the example of a math seminar that began simply as a way to teach calculus to high school teachers. The course instructor, however, decided to use the seminar as a way to encourage the teaching of calculus in all of Chicago's high schools. To do so, he changed the seminar, bringing in both teachers and students to learn calculus in small groups and providing the former with teaching methods they could take back to their schools.

Three years ago, the program began a systematic annual evaluation of the summer seminars. In its first two years, the evaluation was done by a graduate student in public policy. For the last year, the evaluation has been done by Dr. Anne Heinz, a professional evaluator, former teacher, and special assistant to the Chair of the university's Department of Surgery.

Dr. Perlman said that the university's assessment effort was a relatively modest one. Questionnaires were distributed before and after the seminars. In the last two years, questionnaires were sent to teachers during the school year. The postseminar questionnaires asked teachers to report on the changes they had made in their teaching as a result of the seminars. How had the seminar met their expectations? What was the most valuable part? etc.

In summing up, Dr. Perlman said that the program is using the evaluations to help the seminar faculty and its administrators achieve their goals. But this he conceded, has been complicated by the fact that the goals have changed over time. He also said that much of what the program officials had learned from the evaluations confirmed what they had already learned informally—that the seminars are having an important and positive impact on teachers.

Villanova University. Dr. William Marks described Villanova's residential Young Scholars Project in Biology and Mathematics, an outreach program for rising high school juniors and seniors. Out of 900 to 1,000 applicants, the project chooses 40 students from schools in the New York–to–Washington, D.C., urban corridor to participate in a six-week summer program. This combines course work with extensive laboratory and research experience in biology and mathematics. The subject matter is presented in a manner that emphasizes interdisciplinary connections, principles of scientific inference, quantitative thinking, and visualization techniques. Dr. Marks noted that the students are quite diverse: more than half are women, and less than half are white.

One of the major purposes of the program, said Dr. William Fleischman, is to help students who are very interested in biology but lack confidence in math. This focus was based on the experience of many of Villanova's biology majors who drop out of the field because "they can't handle the math," Dr. Fleischman explained.

Another major purpose, Dr. Marks said, is to build a sense of community among the young scholars. To do this, the project has set up a wide range of activities—"life experiences," Dr. Marks called them—designed to encourage the students to interact with one another, as well as the material. In addition, the project includes several activities designed to involve the parents of the students. This sense of community has been crucial in tracking students, with one student often taking the initiative to follow up on the activities of another and reporting the findings to Drs. Marks and Fleischman.

Moreover, the project extends the students' involvement into the academic year. Students do research projects during the school year, and also communicate with one another.

To assess the project, Villanova relies primarily on student responses to an open-ended questionnaire that is submitted at the end of the summer session. Students are asked to give a detailed and frank assessment of every aspect of the program. Student responses are then evaluated, mainly by Dr. Fleischman.

Dr. Marks said that the information gained was "invaluable," but—after hearing the other panel presentations and the plenary on assessment—he added that Villanova's program could probably benefit from collecting more quantitative data.

Discussion

Assessment: A Feedback Device. Much of the discussion explored the benefits and limitations of assessment. The panelists were asked to report on what they had changed in their programs as a result of the assessment process. Dr. Perlman reported that the decision to include students as well as teachers in the summer seminars came in response to feedback from questionnaires. He also said that the University of Chicago had decided to include middle school as well as high school teachers in the program, based on the teachers' evaluations.

Dr. Fleischman reported that in reading the evaluations, he had learned that the students came to the program with a much broader range of abilities in mathematics than in biology. As a result, the mathematics component was given more time to show students the connections between mathematics and biology.

North Carolina State University's Drs. Grant and Berenson reported teachers felt overwhelmed with too much information during the first year's sessions. In later sessions, the levels of information teachers were starting with were assessed, and the summer session was geared to that level.

Do Programs Need a Professional Evaluator? A participant asked the panelists if they really needed to use a professional evaluator to learn what they had accomplished. Dr. Marks responded that Villanova did not use a professional evaluator, but that—after listening to the other panelists and the plenary on assessment—it seemed that a professional evaluation would provide information that would help his program. Dr. Grant said that without a professional evaluator, some key questions might have been missed.

Dr. Heinz expanded on this point. She said that part of her job is to help those who teach in the University of Chicago's program to think clearly about what they are trying to accomplish—to specify their goal. Doing so helps the faculty design and implement an effective program. Someone inside the program, who is not a professional evaluator, might not do as effective a job.

Assessing the Intangibles. Dr. Eric Davies of the University of Nebraska–Lincoln said that one of the key goals of an outreach program is to produce more teachers who are able to get their students excited, which is very hard to measure. Dr. Grant responded that his program relied on anecdotal information and on written responses from students of the teachers who had taken part.

Evidence of Success. The panelists also provided more details about their respective programs in response to questions. Dr. Berenson was asked whether North Carolina State University had any data on how successful her program had been in encouraging rural high school teachers to integrate chemistry, physics, and biology. She replied that the teachers' use of interdisciplinary modules prepared by the program was one measure of success the program evaluation used.

Dr. Heinz said that the University of Chicago's outreach program was trying to leverage its resources to reach more teachers, but it was a complicated matter. The expansion of the program depended on the extent to which university faculty were willing to continue and expand the contacts they made during the summer seminars.

Assessments of Other Outreach Programs. Several of the participants discussed outreach programs at other universities. Dr. Sondra Lazarowitz of the University of Illinois at Urbana–Champaign said that her institution provided summer workshops for rural middle school teachers to help in the development of content and teaching approaches. At these workshops, teachers work in teams to develop kits that are designed to meet their curriculum needs in the classroom. The kits are then tested by the teachers in their schools.

According to Dr. Lazarowitz, the program uses many measures to assess its success. It looks closely at changes in student performance at the schools where its teachers teach, and it analyzes the teachers' professional development. The university also tracks the numbers of teachers who come back to the program from specific schools. She reported a high rate of return of teachers, some of whom came back to act as mentors for other teachers. She also noted that several of the teacher participants had gone on to become science coordinators for their schools or even their districts.

Dr. Harold Silverman of Louisiana State University described his institution's outreach program that aims to improve the teaching of molecular biological concepts in Louisiana schools. The program promotes hands-on approaches to molecular biology by providing teachers with training, curricular materials, and equipment. A key element of the university's program is to provide schools in the state with scientific equipment for classroom use.

Dr. Silverman reported on assessment efforts to date, saying that the program seems to be effective. He based this on teacher participation and the increased numbers of students learning molecular biology through hands-on methods instead of lectures. He said it was too early to draw conclusions about long-term success.

Summary of Key Issues

John Jungck, Ph.D. ■ Mary Mennes Allen, Ph.D. ■ Deidre D. Labat, Ph.D.
Joseph G. Perpich, M.D., J.D.

As context for a discussion of key issues from the program directors meeting, Dr. Joseph Perpich, HHMI Vice President for Grants and Special Programs, gave a brief overview of current efforts to reform kindergarten–12 science education at the national, state, and local levels. He noted the direct impact on undergraduate science.

Science education reform is characterized by conflicting movements. For example, several organizations have established, or are establishing, national curriculum standards for science education, while, at the same time, there is strong support for site-based management in schools. The reconciliation of these two competing objectives is likely to vary widely among school districts. Describing undergraduate science departments as critical players in science education reform, Dr. Perpich told the audience of program directors that they will be affected, now as they design and deliver their outreach programs, and in the future, when the students who have gone through the reformed kindergarten–12 programs reach their institutions.

Current challenges for the science departments include playing an expanded role in teacher education, particularly at the preservice level; ensuring "life after Hughes" by seeking core institutional support for outreach programs; and incorporating technology into science education. The introduction of technology into the science classroom, Dr. Perpich noted, raises many of the issues facing science more generally: issues of costs, equity, and distribution; and issues of broadening access for women and underrepresented minorities. Another challenge for science departments is to develop appropriate assessment tools for evaluating the various dimensions of success of science education.

Defining Success

Dr. Allen discussed several questions that emerged from the program directors meeting concerning assessment. Chief among them is the definition of "success." Although difficult to define, success involves a combination of factors and varies among programs. Not all of the strategies discussed will work in all programs. Determining success involves an examination of the initial objectives of the program. For example, is its goal to produce more well-trained scientists, or a more scientifically literate population?

Beloit College's Dr. John Jungck summarizes the key issues raised during the program directors meeting, along with Drs. Mary Mennes Allen of Wellesley College and Deidre Labat of Xavier University of Louisiana.

A related issue is deciding what variables should be included in an assessment. Dr. Allen noted that many programs are looking increasingly at the impact on the social circumstances of their students, not just the direct impact on performance in science. Again, this issue is tied to the original objectives of the program: should participants be selected by grade point average or their at-risk status? Does the program serve the faculty's need for research assistants or does it serve the needs of at-risk students? Dr. Allen also mentioned that a commonly discussed issue in assessment is the need to establish a basis for comparison, i.e., a control group.

Institutional Differences: One Size Does Not Fit All

Dr. Jungck noted the value of the meeting's discussions in promoting interaction with colleagues with similar interests from a group of institutions that is so heterogenous in terms of geographical location, size, mission, and assumptions about education. These institutional differences have spawned a variety of approaches to science education. The program directors meeting provides an important opportunity for colleagues to learn about the range of approaches and to benefit from the experiences of their counterparts. This point was underscored by Dr. Labat, who observed that a substantial amount of information was shared outside the meeting's formal sessions.

Precollege Programs: A Range of Approaches

Dr. Labat described the wide range of the precollege science education programs discussed during the meeting, indicating that the goals ranged from training future scientists to increasing science literacy among nonscientists. She pointed out that only a relatively limited number of students pursue Ph.D. or M.D. degrees, but all students are personally affected by the advances of science and technology. On a related topic, Dr. Labat pointed out that not everyone who is interested in science will be successful in science. In such instances, she said, it is incumbent on faculty or counselors to be mindful of their approach as they broach that issue with a student, because it is likely to be extremely discouraging.

Discussion

Outreach and Tenure. One program director touched off a brief discussion about outreach and tenure, saying that it is sometimes difficult to attract nontenured faculty to an outreach program because of the demands of the tenure process. He asked HHMI to consider possible ways to encourage nontenured faculty participation, such as providing a forum for publishing papers or articles. Dr. Jungck noted that existing journals offer publishing opportunities, and encouraged the audience to share their wealth of experiences in the relevant scientific and educational publications such as the *Journal of College Science Teaching, Science Education*, and *American Biology Teacher*. Dr. Perpich noted that several institutions have incorporated outreach requirements in their tenure processes, and he encouraged directors from those institutions to share their experiences on this issue.

Women and Minorities in Science. One common goal among the undergraduate programs is to attract women and underrepresented minorities to science. An audience member observed that reaching women and minorities at majority institutions requires a commitment by the faculty and the personal attention of program directors. Another program director indicated that there is a need for the HHMI to encourage more Ph.D.'s in biology in order to help reverse the past decade's decline in the number of minority Ph.D.'s, particularly among African Americans. He suggested that one contributing factor to the decline is that, in general, the M.D. degree is better known than the Ph.D. degree within minority communities. Dr. Purnell Choppin, HHMI President, explained that while HHMI is a medical research institute, the vast majority of investigators supported are Ph.D.'s.

External Influences. A critical issue in assessment is separating the true impact of science education programs from the influence of external social and economic factors. A program director cited the example of the role of an outreach program in college enrollment. The program directors agreed that the external influences are difficult to account for, but Dr. Allen noted that they may be easier to factor out when the assessment is done over a period of time. The role of external factors was illustrated in Dr. Perpich's comments to the effect that shifts in student career interests and changes in state teacher certification requirements had led to the demise of the education major at Oberlin College, which at one time had graduated 200 future teachers a year.

Program Directors Network. There was substantial discussion of the need for a forum to exchange ideas so that program directors can get new ideas and insights and avoid the pitfalls others may have encountered. It was noted that published articles tend to focus on successes, but that program directors would benefit tremendously from learning about failed approaches. It was announced that a separate folder will be created on the HughesNet as a repository for assessment questionnaires and other assessment resources. Another suggestion was that HHMI maintain an index of relevant articles on E-mail.

Ms. Linda Chaput, President of Interactive Services (a commercial publisher), advised the program directors not to worry if they feel that they are missing the educational technology bandwagon. She said that while everyone now is "scrambling for a seat at the table, the table itself is getting larger," as there is increased interest in delivering education and reference materials electronically.

Dr. Perpich concluded the session by recapitulating some of the major ideas from the program directors meeting:

- **Precollege Science Education.** Colleges and universities must place greater emphasis on training kindergarten–12 teachers, both in-service and preservice. Dr. Bruce Alberts, President of the National Academy of Sciences, is calling on science departments to recognize precollege programs as part of their mission. He is also encouraging institutions of higher education to form science education partnerships with local schools and communities. While the mission of HHMI is to attract more students to biomedical research, the Institute places significant resources in kindergarten–12 science education outreach programs to expose large numbers of young people to science broadly and increase science literacy in the general population.
- **Educational Technology.** The costs are coming down and more software is being developed and upgraded, but educational technology is still an unexplored frontier for many science departments. A number of the meeting participants, including Drs. Gabriele Wienhausen and Barbara Sawrey of the University of California–San Diego, have significant experience in assessing educational technology, particularly the use of multimedia models to help students prepare for their laboratories. These programs' efforts have been profiled in *Chemical and Engineering News*. Dr. Perpich expressed

strong interest in learning as much as possible about the use of educational technologies by the program directors over the next year. One issue in particular is how educational technology responds to the differing learning styles, preferences, and abilities of students.

■ **Assessment.** There is no right way to assess the science education programs, and evaluation must be customized to fit their structure and objectives. A common issue in any assessment is the difficulty of teasing out the effects of external trends on such outcomes as enrollment levels and interest in science as a career. Other issues include costs, and whether or not to use outside evaluators. Some institutions continue to have questions about how much assessment is needed, or why assessment is needed at all.

Dr. Exyie C. Ryder of Southern University and A&M College at Baton Rouge takes note of an important point.

Programs at a Glance: Overview of 1994 Meeting Participants by Activity*

Institution	Undergraduates: Research	Undergraduates: Research, Presentations, Meetings	Undergraduates: Scholarships	Undergraduates: Tutoring, Counseling, Mentoring	Undergraduates: Minorities, Women	Preservice Experience, Courses	Curriculum Development, Reform	Educational Technology	Assessment, Tracking	Page Numbers
Arizona State U.	X	X			X		X			130
Bates College	X						X			189
Beloit College	X	X					X	X		142
Carnegie Mellon U.	X			X	X		X	X		195
CUNY–City College	X									134
Harvard U.	X				X		X	X		148
N.C. State U.	X					X	X		X	206
Oberlin College	X	X			X	X				116
Smith College	X	X			X					98
SUNY–Binghamton	X				X	X	X			121
Tuskegee U.	X				X			X	X	174
U. of Arizona	X	X				X		X	X	157
U. of Calif.–Davis	X				X		X			138
U. of Calif.–L.A.	X			X	X		X	X		200
U. of Calif.–San Diego	X				X			X	X	162
U. of Chicago	X						X		X	211
U. of Colorado–Boulder	X				X	X	X	X		104
U. of Mich.–Ann Arbor	X			X	X		X	X	X	179
U. of Nebr.–Lincoln						X	X	X		126
U. of Puerto Rico–May.	X	X			X			X		152
U. of Wisc.–Madison	X	X					X			110
Villanova U.	X			X	X		X		X	216
Wellesley College	X			X	X				X	169
Williams College	X			X					X	183
Xavier U. of La.	X		X	X	X					93

*This chart summarizes the activities of the undergraduate science education programs that were presented at the 1994 meeting. It is based on the program profiles contained in this report, and does not necessarily reflect the entire scope of activities either of the programs indicated here or of other undergraduate programs supported by HHMI.

Strategies to Involve Faculty in Outreach

Xavier University of Louisiana, 93

The Role of Science Departments in In-Service Science Education

Smith College, 98
University of Colorado at Boulder, 104
University of Wisconsin–Madison, 110

Preparing Tomorrow's Science Teachers

Oberlin College, 116
State University of New York at Binghamton, 121
University of Nebraska–Lincoln, 126

Programs for Community College Faculty and Students

Arizona State University, 130
City University of New York City College, 134
University of California–Davis, 138

Strategies to Involve Faculty in Outreach Xavier University of Louisiana

Xavier University of Louisiana is a private, historically black, comprehensive institution in New Orleans. In 1993 the Howard Hughes Medical Institute awarded the University $1,400,000 to support a program for attracting and retaining students in the sciences, including women and members of underrepresented minority groups, through the following activities: (1) academic development and other support for biology and chemistry majors, to include financial assistance for freshmen, academic advising for biology and chemistry students through counseling and tutoring, and placement in summer laboratory research programs, and (2) summer academic enrichment programs in biology, chemistry, and mathematics for 9th–12th-grade students primarily from metropolitan New Orleans, and support for junior high and high school teachers to develop new teaching materials.

Pathway Programs

With a total of 49 acceptances, Xavier University of Louisiana was the nation's leading producer of African Americans entering medical school in 1993. Over the past five years, the University has doubled the number of African American graduates it sends to professional and graduate schools in the biological sciences and tripled the number of students majoring in biology.

The University's feat stems to some extent from the strength of four precollege programs, partly supported since 1988 by HHMI funding. These programs form the first stretch of an educational pathway that nurtures promising science students from junior high school into college.

Three of the programs—MathStar, BioStar, and ChemStar—are taught by Xavier professors with the assistance of undergraduates. The other, Stress On Analytical Reasoning (SOAR), is taught in conjunction with high school teachers. These programs share a number of elements aimed at retaining student interest: a focus on problem-solving rather than content, group competition, and peer support, with upper-level mathematics and science majors as teaching assistants and role models.

For two decades, the pathway effort has been successful in recruiting University faculty to develop and run its precollege programs. That success, program leaders say, results from faculty-enlistment strategies—some natural, others deliberate—found in the structure, characteristics, and operation of the effort as well as in the personalities of its leaders.

Program Structure

"First you have to have a catalyst," says Dr. Jacqueline Hunter, a biology professor who has participated in the pathway effort since its start in the mid-1970s, "a person who has all these ideas, who is willing to do most of the work, but who can convince somebody that it's worthwhile, you ought to do it."

The Xavier effort is catalyzed by chemistry professor Dr. JW Carmichael. With the aid of student helpers in the Premedical Office he does a great deal of the work behind the project and generates an energy that pulls in faculty volunteers.

Another key structural strategy in Xavier's success—the Science Education Research Group (SERG)—is a long-standing core of faculty that includes Drs. Hunter and Carmichael and a half dozen others. The group provides support for its members and a place to discuss education issues, solve teaching problems, and publish reports.

"We don't just talk about how to get grants," said Dr. Deidre Labat, Chair of the Biology Department and HHMI program director. "We discuss how to make up tests, what kinds of questions, how many levels of information you can put in a question. We talk about articles in science education and ways to improve what we're doing."

From 6 to 25 faculty members have been attending these meetings once a week throughout the academic year since 1975–1976, when representatives from the biology, chemistry, mathematics, physics, and computer science departments were called together to create SERG. After developing the program, the group continued to meet.

The interdisciplinary approach allowed strengths to be shared among the departments and benefited everyone. For example, it became apparent that Biology had a better tutoring center than other departments, and Chemistry had made innovative improvements to freshman courses.

Program Characteristics

The precollege pathway programs serve about 600 students each summer. To persuade faculty beyond the core group to participate, the programs must be viewed as both worthwhile and successful, say the members of SERG.

The worth of the precollege programs is evident in the large numbers of students who want to attend. In 1994 more than 2,000 applied. Their value is also reflected in the understanding of most faculty that for many of these students, the precollege programs are the only real hope of a successful college education. "We know that if we don't intervene with these students, we're going to lose them," said Dr. Labat.

In addition, the SERG members have made deliberate attempts to communicate the value of the pathway programs. When anecdotal evidence indicated that Xavier students who had passed a college-level reading ex?m could not understand the standard biology text, these professors called other science faculty to a meeting and demonstrated the problem. Faculty were given the reading exam and then asked to read a section of the biology book. It was obvious that the reading test was not a suitable indicator of comprehension.

The demonstration also persuaded faculty of the value of general vocabulary building for science students. Many volunteered to help write the 2,500 test questions that eventually became "Vocabulary for the College-Bound Student," now used in the SOAR program.

According to Dr. Carmichael, convincing the faculty that the outreach effort has produced worthwhile results is the most effective way to get them to volunteer time for the students. The success of the precollege programs has also been persuasive in getting more faculty and science departments involved. The takeoff of SOAR and the parallel evolution of an off-campus program into ChemStar in the mid-1980s generated a surge in Xavier's chemistry enrollments. Dr. Labat concluded that the Biology Department should have a precollege summer program, too. With the help of Sr. Grace Mary Flickinger, another member of the biology faculty, BioStar was started in 1985, when about 50 Xavier students were majoring in biology. Nine years later, the Biology Department has about 750 majors. A similar sequence of events led to the creation in 1986 of MathStar.

Program Operations

The Science Education Research Group uses a half dozen strategies to involve faculty in the pathway precollege programs. The SERG professors actively recruit new faculty, relieve them of program administrative work, prepare teaching materials for them, handle disciplinary problems in their classes, consider their ideas for program changes, and reward their participation in a variety of ways.

In fact, recruitment begins during the hiring process. Candidates for the biology, chemistry, and mathematics departments are told about the pathway effort and asked whether they can participate. Most of them do.

The next recruitment stage is keeping the science faculty informed. Whether they attend or not, all science faculty receive agendas and minutes for each meeting. When an instructor is needed for one of the summer programs, SERG begins to publicize the opening.

If this approach does not produce results, Dr. Carmichael seeks out new faculty members who show promise for teaching in the summer programs and explains to them individually what this commitment would involve. Although the group tries not to pressure new faculty unduly, it wants to afford them every opportunity to participate if they wish. At Xavier, participation in teaching-improvement activities is seen as advantageous to a professor's academic career.

When recruiting faculty, Dr. Carmichael also includes an appeal to help the nation's young African Americans. "I would always put in something about [the students'] needing them," he said. "I would be up front—we need somebody to do this, we need somebody who can teach kids, inspire them."

The Premedical Office handles most of the administrative chores for faculty participants. It recruits students for all four summer programs and frequently processes the applications. It also does much of the secretarial work for program development projects st h as creation of the vocabulary-building text. The SERG professors have already prepared teaching guides for the summer courses, so new faculty can step into class with minimal preparation time.

When teaching in the precollege programs, faculty spend little of their time dealing with discipline, since the undergraduate assistants have been assigned to handle such problems. This arrangement emerged after the SERG professors noticed that high school students were loitering after lunch instead of hurrying back to class. So they were organized into competing groups, with an undergraduate assigned to lead each group. Groups win points for good attendance as well as for academic performance, while group leaders provide role models and maintain order.

SERG provides opportunities for faculty volunteers to revise the teaching workbooks so they will feel that they are part of the outreach effort.

Faculty involvement in SERG meetings is formally recorded in the minutes, and many list their participation on the faculty update sheets that are sent each September to the University's Vice President for Academic Affairs. Faculty members who work in a precollege program receive a thank-you letter, and a copy is sent to the department chair. Dr. Labat acknowledged that when faculty are up for promotion, rank, and tenure, these activities are a significant factor.

Xavier also recognizes the publication of science education articles as a sign of professional activity, and the SERG professors have published some 30 articles about their work.

Dr. Carmichael commented that the goal of publishing is twofold. The first is to educate others about the program; the second is to provide documentation of success in a traditional format. For example, Xavier is cited repeatedly in the literature on

African Americans and higher education, and science education in general.

The New Pedagogy

Dr. Carmichael spoke about the evolution of a more nurturing faculty attitude toward students. This, he feels, began with dropping the gatekeeper attitude that characterized science faculty in the post-Sputnik era, a time when many people wanted to go into the sciences, but there were not enough positions for them. So the faculty had to create a gatekeeping system that allowed only the best students through.

"The world is not like that today," he said. "We are no longer in a situation where the nation can afford to throw away a lot of talent just because we are not ready when [they enter] college."

Nor can the nation afford professors who are not good teachers. Dr. Carmichael recalled that when he was a new professor at a research-oriented university, his department chair told him not to devote his time to the freshman course he was teaching, but to research. It is also important that professors apply the same skeptical, testing approach to ideas about teaching that they apply to scientific ideas. Try something and test it, he said; if it works, keep it. If it doesn't, then modify it or try something new.

The strategies that the Science Education Research Group has used so successfully at Xavier can be replicated elsewhere. "If they buy into a couple of key ideas," Dr. Carmichael said, "I think other people could do it."

Program Director

Deidre D. Labat, Ph.D.
Associate Dean of Arts and Sciences
Xavier University of Louisiana
7325 Palmetto Street
New Orleans, LA 70125
(504) 483-7652
(504) 483-7527 (laboratory)
(504) 486-0301 or 482-1561 (fax)

Institutional Profile

Total enrollment	3,145
Undergraduate enrollment	2,837
Number of faculty members	252
Endowment (millions)	$17
Annual budget (millions)	$30

The Role of Science Departments in In-Service Education Smith College

Smith College is a private liberal arts institution in Northampton, Massachusetts. In 1993 the Howard Hughes Medical Institute awarded the College $600,000 in support of (1) equipment acquisitions for undergraduate laboratories, such as cell biology, immunology, and neuroscience; (2) a summer undergraduate research program, including student stipends, research supplies, and travel to scientific meetings; and (3) outreach programs that encourage young women to take math and science throughout high schools and pursue careers in science.

Addressing Gender Bias in Science Classes

Many girls face a number of social factors that may inhibit them from going into science. Peer pressure, few role models, unequal treatment in the classroom, and ineffective career counseling can cause girls to leave science before high school. One way in which Smith College is addressing these issues is through the Current Students/Future Scientists and Engineers program.

The program focuses on teachers and guidance counselors—both of whom are extremely influential in shaping student careers—and provides them with a variety of resources and hands-on experiences designed to interest them in science and increase their awareness of gender biases that may exist in their own schools and classrooms. With its 1993 Institute grant, the college has extended the program developed under its 1988 award by enriching the program's laboratory component and enabling increased numbers of teachers and counselors to participate.

Through the yearlong program, the teachers and counselors address gender bias in the classroom and in career preparation programs by developing strategies that are individually tailored for their own schools. Creating teacher-counselor teams is a key component of the program, according to Casey Clark, Science Outreach Program Coordinator and Co-Director of the Current Students/Future Scientists and Engineers program.

Many teachers and counselors do not have the opportunity to collaborate in the school setting, so the Smith program helps by providing them such opportunities. Involving guidance counselors is a unique and important feature, Ms. Clark said, because of their influence in selecting courses and in shaping careers. She emphasized the importance of providing counselors with a positive, hands-on laboratory experience as well as strategies and resources to stimulate student interest in math and science.

The specific goals of the program are

- To encourage young women students of all abilities, especially underrepresented and underserved minorities, to take math and science courses throughout high school.
- To develop strategies that will help to eliminate obstacles encountered by young women and minorities in their pursuit of science and math.
- To provide concrete information about career opportunities for women who are interested in science and engineering.
- To share workshop goals with staff, students, and parents through the development of implementation plans in the school community.

Developing a Team Approach

The yearlong program starts during the summer, when teacher-counselor teams come to the Smith campus for a three-day workshop. Typically, 25–30 teams take part in the workshop. They hear presentations by successful women in science, including minority scientists, past workshop participants, and national authorities on education and bias. The 1994 keynote speaker was Sheila Tobias, author of a number of books on science education, including *Overcoming Math Anxiety.*

Participants, who come from a variety of geographical and socioeconomic settings, receive a stipend plus room and board. They attend panels and seminars on such topics as "Problems and Solutions: Teaching Girls in Math and Science" and "Women's Experience in Science and Engineering Careers: Merging the Personal with the Professional." The programs are designed by a planning committee of Smith faculty, industry representatives, secondary school administrators, and past workshop participants, who in many cases also serve as presenters.

During one summer workshop, Drs. David and Myra Sadker, researchers and authors on gender issues in education, led a seminar to train the teachers and counselors to recognize and address gender bias in classroom interactions. Participants were asked to evaluate the equity and effectiveness of the teaching style used on a videotaped class and were taught observation strategies. Role playing also was used to illustrate gender bias in teacher-student interactions. Several of the participating teachers have noted the importance of becoming sensitized to the subtle forms of discrimination that can occur in the classroom.

The workshop also offers laboratory experiences in biology, chemistry, mathematics, and physics, and provides training in electronic communication. The laboratories feature hands-on experiments that engage the participants in the scientific process. Some of these activities can be easily adopted and used by secondary school teachers.

In the summer of 1994, teachers and counselors participated in a laboratory on "Exploring the Structure and Function of the Cardiovascular and Respiratory Systems." This laboratory was specifically designed for participants to become engrossed in activities without being "grossed out" by the use of fresh tissue. In "Lasers: The Light Fantastic," participants assembled a helium-neon laser and learned about the properties and applications of lasers.

The program also offered a Computer Communications lab, in which the teachers and counselors learned how to connect with colleagues and exchange curriculum materials and other information via electronic bulletin boards and computer networks. The summer program marked the first time that the College has integrated the programs for high school students and teachers with that for the counselors. A goal of this approach is to bring together students, teachers, and counselors from the same schools, thereby broadening the participation in both programs and enhancing team building.

School Implementation Plans

At the end of the summer workshop, each of the teams draws on its experience to develop a plan to be implemented during the upcoming school year. Here the team approach again proves valuable. Every implementation plan is different. But in most cases, they are based partly on the workshop format, particularly in having women and minorities as guest speakers and mentors to talk with students about their own experiences in choosing and succeeding in their particular area of science or math. Other common elements include providing hands-on science opportunities for students and activities designed to raise awareness among students, teachers, parents, and administrators about gender bias in school. These activities range from developing literature to conducting seminars.

The teams tend to tie their plans into the school's existing structures—departmental meetings, assemblies, Career Day events, science classes, counseling sessions—to inform their colleagues and students about opportunities for women in science. Outside activities may include taking field trips, establishing support groups for girls in science, and evaluating course prerequisites to encourage girls and underrepresented minorities in higher-level math and science courses.

The plans have included a number of unique approaches. At one high school, the team arranged for all 9th-grade science students to interview women in science careers and publish the results in a booklet. The desired outcome would be an increased level of interest in science in the 9th-grade girls, which would be indicated by whether they take science courses in later grades, whether they take achievement tests in science and math, and whether they apply to college with the intention of becoming science majors.

At another high school, the team decided to have students use basic scientific methods of inquiry to learn about classroom gender issues. Their plan called for students to develop hypotheses and create surveys to address such topics as how math is used in careers, and student perception of the value of math in their future studies or career. The students would then be responsible for compiling, analyzing, and presenting the data.

Acting on Principals

Feedback from the workshop teams has indicated that it often requires a special effort to gain the support of school administrators for the proposed activities. Consequently, the program directors also routinely contact school principals and superintendents to give visibility to what the teams are doing and ask for their backing.

John O'Neill, a biology teacher from Bellamy School in Chicopee, Massachusetts, said that his principal encouraged him to speak to the other teachers in his school about his Smith College experience. That opportunity led to other presentations, which have engendered additional involvement by the teaching staff, including those in other subjects—social studies, reading, English.

Throughout the year, Smith faculty and staff members maintain contact with participants through regular mailings that include a variety of substantive resource materials such as relevant articles and updates on various activities associated with the program. During the spring, the teams return to the College to present and evaluate their plans, and a final report containing all the plans is issued.

Prior to receiving HHMI funding, the Smith College workshops had already resulted in programs designed to recruit and retain young women in science and math courses in 130 New England school districts. With the Institute's support, Smith has expanded the focus of the program to include more underrepresented minority students and can offer it to more school systems across a wider geographic area.

In 1994, the workshop participants came from schools that serve predominantly low-income, underrepresented student populations. Teams were from Massachusetts (supported by state funds), New York, Pennsylvania, and Wisconsin, including middle school teams, high school teams, junior high teams, and a private school team. Since the beginning of the program, over 500 teachers and counselors from nearly 200 schools have participated, with the implementation plans reaching over 22,000 students in grades 5 through 12.

The Student Perspective: Smith Summer Science Program

In 1994, funding from the Institute supported the participation of eight teacher-counselor teams in the Current Students/Future Scientists and Engineers program. In addition, the Institute supported scholarships for high school students on these teacher-counselor teams to attend the Smith Summer Science Program (SSSP), a four-week residential science camp for girls with demonstrated talents and interests in science. With the help of matching funds from two teams' sites, scholarships were extended to support 11 high school girls. Eight of these students were underrepresented minority students and all were financially disadvantaged.

While they were on campus for the month of July, the students participated in group research projects with Smith faculty in chemistry, physics, biology, and psychology. Although participants are chosen for their high academic qualifications, the SSSP environment emphasizes cooperative learning and discourages competition.

Students were immersed in a cooperative, hands-on learning environment, where they carried out a diverse set of activities that included building electronic musical instruments and lasers, exploring and synthesizing chemical polymers, conducting field studies on social stereotypes, and investigating the role of biotechnology in world food crop production.

In addition, the students met to discuss careers in science with women in the fields of biotechnology, health care, applied and basic research, and engineering. They also attended workshops on college admissions, financial aid, and career development.

Teachers and counselors joined their students midway through the SSSP to celebrate their accomplishments, attend the students' research presentations, and participate in the Current Students/Future Scientists and Engineers Workshop. Students, teachers, and counselors met with Gail Scordilis, Director of the SSSP, and Casey Clark and Jeanne Powell, Co-Directors of the Current Students/Future Scientists and Engineers program, to discuss how they could all work together in formulating an implementation plan for their schools. The strong support from their teachers and counselors was evident in the students' enthusiastic responses.

The addition of the student perspective to the Current Students/Future Scientists and Engineers program is expected to strengthen the program and add to its uniqueness. In addition, the Institute's support of the linkage of these two outreach efforts has significantly enhanced the follow-up support for students in their own schools. This is particularly significant for those underrepresented minority students who are perceived to be at the greatest risk for dropping out of science. The link with the Smith Summer Science Program has extended the impact of the Current Students program beyond New England.

Program Director

Thomas S. Litwin, Ph.D.

Director of the Science Center and Adjunct Associate Professor of Biological Sciences

Clark Science Center

Smith College

Northampton, MA 01063

(413) 585-3801

(413) 585-3786 (fax)

TLITWIN@SCIENCE.SMITH.EDU (Bitnet)

Institutional Profile

Total enrollment	2,923
Undergraduate enrollment	2,794
Number of faculty members	261
Endowment (millions)	$453
Annual budget (millions)	$107

The Role of Science Departments in In-Service Education University of Colorado at Boulder

The University of Colorado at Boulder is a public research institution. In 1989 the Howard Hughes Medical Institute awarded the University $2,000,000 to (1) provide opportunities to undergraduate students, including women, blacks, Hispanics, and Native Americans, to participate with faculty scientists in conducting bioscience research; (2) establish new and enhance existing introductory and advanced laboratory courses focused on such fields as biochemistry, neurobiology, physiology, and molecular biology, with exposure to state-of-the-art technology in research methodology; (3) procure laboratory equipment and access to database information for use in research and course work; and (4) offer research and educational opportunities in the biosciences to precollege faculty and students.

A Unique Opportunity

University science departments like those of the University of Colorado at Boulder are in a unique position to provide in-service training to teachers because they can supply the science and science-related courses not readily available to teachers through other avenues. In fact, elementary and high school teachers who want to upgrade their scientific knowledge and skills often face a void. Although many in-service courses in teaching methodology exist, few offer meaningful scientific content. And schools of education, which traditionally offer such courses, do not usually have professors of biology or chemistry.

"The departments are where the content is," said Dr. Mark W. Dubin, Associate Vice-Chancellor for Academic Affairs and HHMI program director. "They have the faculty, the people who know what's happening in their area... of science. They are the places where resources exist for developing and delivering programmatic content."

The in-service component of the HHMI program offers one- and two-day workshops, (e.g., Forensic Botany, DNA Electrophoresis, Stream Ecology, Yeast—Beyond Bread and Beer), longer courses over several Saturdays or during the summer (e.g., Practical Botany, Topics in Molecular Biology, Drugs and the Nervous System, Topics in Biotechnology), and research opportunities for teachers each summer. The program's Science Squad, graduate students who help teachers introduce hands-on science to their students, also plays a major role in the in-service effort. Undergraduates are also involved by assisting at the Bioscience Institute and in the workshops for teachers.

The Bioscience Institute, also supported by the HHMI grant, brings about 30 inner-city high school students and two science teachers to the campus on Saturdays for a series of bioscience workshops. These involve laboratories, lectures, and a range of college-related activities such as eating in a dormitory, meeting minority University students, and admissions counseling. The institute serves secondarily as in-service training for the accompanying teachers. The equipment awards, which fund small purchases of equipment and supplies for science instruction, help teachers implement in the classroom what they have learned via in-service courses or the Science Squad.

Other components of the program support master teachers, provide undergraduate research apprenticeships and opportunities, and fund curricular and laboratory development in the departments of biology, chemistry/biochemistry, chemical engineering (biotechnology), and psychology (neurobiology).

The program has succeeded in its teacher outreach effort by bridging the supply side—the science departments—and the demand side of in-service training. The success of that linkage comes from responding to teacher needs, providing continuity—the program has a five-year history of continuous operation—and reimbursing faculty and teachers for their contributions to the process.

"[Success depends upon] sensitivity to needs, consistency, and actually paying the real costs," Dr. Dubin said. "If you miss those pieces, any of them, [the program] is going to fail."

A Structure to Support Faculty

Science faculty are generally enthusiastic about providing enrichment for precollege teachers, Dr. Dubin said, and it is easy to assume that enthusiastic levels of participation will follow. But faculty do not have much time to give, and many burn out after teaching one course because of having to deal with the nonteaching details of in-service education. Nor do their individual departments have the time, money, or staff to run in-service programs. As a result, a college or university has to take on the responsibility of providing the infrastructure, which might be very difficult for a science department to do on its own.

The HHMI program, operated through the vice-chancellor's office, provides an infrastructure that leaves science departments free to concentrate on instruction. The program handles the administration of in-service offerings, investigates what kind of courses teachers want, prepares course brochures, recruits and registers participants, and pays faculty to develop or teach courses.

"Unless [the faculty] have the structure, it's very difficult for them to do [the in-service training]," said Julie Graf, HHMI pro-

Josefina Higa, a West High School teacher, and West High School students Josefa Loya and Fabiola Cabral conduct an experiment during the Hughes High School Bioscience Institute.

gram coordinator. "[The program] provides the structure and legwork, and we're asking for something very specific from [the faculty]." The instruction workload is further lightened by spreading it among many in the science departments, including undergraduate and graduate students, postdoctoral fellows, and research associates.

The grant has made possible the creation of a structure that makes participation relatively easy for faculty. "As concepts go, this is not a unique or difficult thing to invent. What's hard is to have the financial resources to pay for the human resources to deliver a high-quality, long-term, consistent program," Dr. Dubin said.

When the HHMI support is finished, other sources of funding will be sought to ensure that the in-service structure provided by the program will be a permanent bridge between science faculty and precollege teachers, he added.

Sensitivity to Teacher Needs

While support is essential on the faculty side of in-service training, trust is crucial on the teachers' side. Teachers know well that some programs come and go quickly while others do not produce results. Often they are wary after such experiences. That is why gaining the teachers' trust is especially important.

Central to building trust has been employing staff with a background in precollege as well as university science education. Ms. Graf is a certified science teacher with experience in middle and high schools and has worked in a university science laboratory. Dr. Louisa Stark, the scientist-in-residence who works with the HHMI program, gained experience in precollege classrooms as a member of the Science Squad before receiving her Ph.D.

To gain the trust of the teachers they work with, program staff must be sensitive to teacher needs. This means listening carefully, presenting useful in-service programs, and responding to teacher suggestions for altering programs or starting new ones. In addition, staff need to maintain a long-term presence, following up on questions and problems that arise as teachers try their new knowledge and skills in the classroom. These qualities attracted Ruth Baldivia, a science teacher at West High School in Denver with a student population that is about 80 percent Hispanic, to the University's in-service courses.

"The thing that I appreciate most about the program at Boulder is Julie's involvement and her ability to listen and take into consideration what needs to be done. I feel like [the staff] listen to the teachers and are not just going with [their own agenda]," Ms. Baldivia said.

Another form of sensitivity is to offer teachers an array of in-service options, Ms. Graf said. "If you have a menu for them to choose from, they can fashion what fits best into their schedule and what is most beneficial to them, so they're really utilizing their time in ways that they perceive as valuable. They develop a certain ownership of what they decide they'd like to do."

Ms. Baldivia has participated in all five of the in-service offerings. She has taken courses in ecology and biotechnology, used Science Squad members in her classes, won equipment awards, and participated in the Bioscience Institute. She has also conducted summer research on the molecular genetics of soybean plants in the laboratory of Dr. Kathleen Danna.

Her experience illustrates still another form of sensitivity: responding to teacher input. In one instance, Ms. Baldivia and others suggested that lesson assignments for in-service courses should be more rigorous and practical so that teachers could translate their experiences to the classrooms. Their recommendation was that teachers be required to develop lesson plans based on the courses they attended, which is now standard practice.

Another instance involved the Science Squad, whose graduate student members visit schools every week or so throughout the year, bringing hands-on science exercises, laboratory modules, science expertise, and ideas. They help teachers set up and modify science activities, and provide follow-up service to troubleshoot problems.

Ms. Baldivia requested a minority Science Squad member to serve as a role model for her students. During 1993–1994, Science Squad member Jorge Ortiz-Zagas was assigned to work with West High School students, mostly those whose

Arath Resendez, Tim Maine, Edgar Martinez (students at West High School), and Tracy Benning, a University of Colorado at Boulder graduate student, examine samples during the Hughes High School Bioscience Institute.

first language is Spanish. He explained how an experiment is done, helped with their science projects, and demonstrated his own work. He also took students out to do water tests on the South Platte River, which runs near the school.

A third instance of sensitivity to teacher input—creation of the Bioscience Institute—began at a post-meeting dinner discussion among four science teachers and Ms. Graf. Since West High School has a high dropout rate and few students enter college, in part because they are intimidated and do not know what the college world is like, the teachers saw a need to familiarize these students with a university environment to motivate them toward pursuing a higher education. The program responded by establishing the Bioscience Institute, which benefits both students and teachers.

Continuity

Continuity plays a critical role in building trust for in-service programs. Teachers need to know that follow-up help is available when they try to implement what they have learned in an in-service course, when they have problems with hands-on science activities, and when they need to learn how to use new equipment.

"If you do not have consistency, you [cannot have] success," Dr. Dubin said. "From the teachers' side, it's almost the only part that counts."

The program offers several forms of follow-up. The staff advise teachers over the phone or in person. Science Squad members frequently troubleshoot problems with new science modules during periodic visits to the schools. And the program provides equipment-training workshops as particular needs arise. When several teachers requested electrophoresis devices as their equipment awards, a weekend workshop was organized to train the teachers to use them.

Continuity also helps propagate the in-service program. As one or two teachers come to trust and use the program, they draw in others until the school's entire science department becomes involved, Dr. Dubin said. New teachers join the program when they arrive, and long-time participants take it with them when they leave. "Once you have teachers as members of the program and they have some sense of ownership, [when] they switch schools, they bring you right in to the new school," he said. "They call and say, I've moved, can you help us over here now?"

The University's science departments play a major role in in-service education by providing science content the teachers cannot get elsewhere. On their side of in-service training, teachers play a leading role in defining and refining the offerings. The two communities are linked by a university-level structure that catalyzes the process. Together, these entities—science departments, teachers, and the HHMI program—present an array of in-service opportunities that truly benefit precollege science teachers.

"We have a continuing and multifaceted relationship that can be taken advantage of in different ways," Dr. Dubin said. "That's part of the genius of it. It has more than one piece, and the pieces are synergistic."

Program Director

Mark William Dubin, Ph.D.
Associate Vice Chancellor
for Academic Affairs
Campus Box 40
University of Colorado
Boulder, CO 80309 0040
(303) 492-5094
(303) 492-8861 (fax)
DUBIN@COLORADO.EDU (Internet)

Institutional Profile

Total enrollment	21,748
Undergraduate enrollment	19,026
Number of faculty members	2,373
Endowment (millions)	$54.3
Annual budget (millions)	$455

The Role of Science Departments in In-Service Education University of Wisconsin–Madison

The University of Wisconsin–Madison is a public research institution. In 1989 the Howard Hughes Medical Institute awarded the University $1,200,000 for a program to include (1) organizing and facilitating student research placements and providing students with opportunities to present research findings in seminars, journals, and other forums; (2) faculty development; (3) curriculum development focused on integrating academic programs within the biological sciences; and (4) outreach initiatives to science teachers from middle and high schools throughout Wisconsin.

Networks for Teacher Development

At the University of Wisconsin–Madison, the Biological Sciences Division comprises approximately 740 faculty members in 68 academic departments and programs. To marshal the substantial scientific resources available in the division for precollege teacher training, the University's Center for Biology Education encourages the involvement of research scientists in precollege outreach and coordinates their activities. According to Dr. Paul Williams, Professor of Plant Pathology and program director, the Institute's grant has been used, in part, to support programs that provide Wisconsin public school teachers access to the University's Biological Sciences Division.

One of the principal ways in which the Center supports precollege teachers is by providing them with an array of in-service education and training programs. The Institute's grant provides support for team projects involving University science faculty members and teachers. These mini-grants bring together teachers and research scientists (including students) to create new educational materials.

The mini-grants program has supported a variety of activities that have resulted in products the teachers can take back to their classrooms for practical use. The Center has produced materials for classroom units on genetics, covering such topics as genotype, phenotype, and epigenetic traits, and on cell biology, which has provided demonstrations of meiosis using simple materials.

In another project, Wisconsin elementary school teachers have worked with University scientists in developing a new classroom module on genetics. These teachers, in turn, have served as trainers for other teachers, and have conducted regional workshops on integrating the new material into classroom teaching. Using sea urchin fertilization as a model, elementary, middle, and high school teachers have taught principles of cells, reproduction, and growth. In this project—Womb with a View—urchin gametes were spawned with mild salt solutions, and eggs and sperm were collected. The events of early fertilization and first mitotic division were viewed easily under the microscope. Additional workshops were held to inform other teachers of the exercises.

In other cases, the grants have supported efforts for teachers to collaborate with one another and with University scientists in ongoing educational activities. For example, in 1991 a mini-grant helped Sharon Nelson, a science teacher at Waunakee High School in Madison, Wisconsin, establish BioNet, a network of educators who share teaching expertise, update their knowledge of biology, and establish alliances with university biologists and science educators.

BioNet began as a local network, bringing together biology teachers who lived within 50 miles of Madison and putting them in contact with University of Wisconsin–Madison researchers. Success at the local level led to BioNet's expansion into a statewide network that now brings more than 500 teachers from 12 Wisconsin regions into contact with local colleges, universities, businesses, and industry.

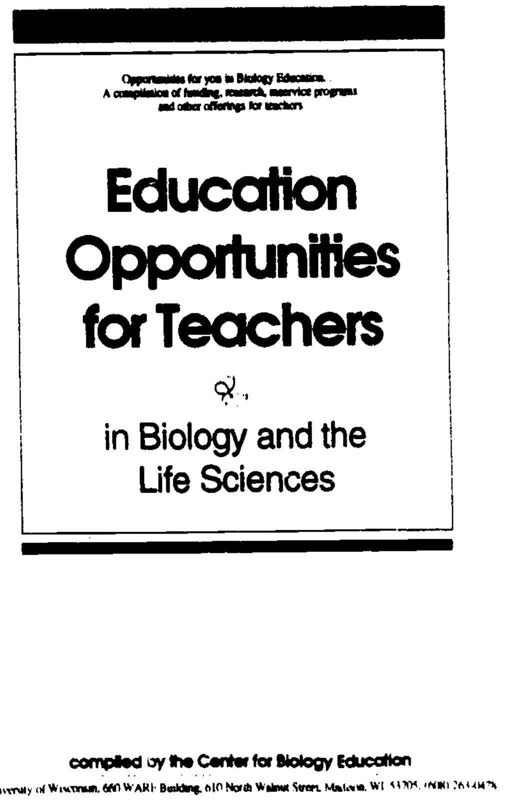
BioNet teachers attend several meetings a year where they hear a presentation by a guest speaker (typically a university researcher) and a featured curricular activity presented by a local teacher, and where they share teaching activities and ideas. Susan Johnson, who teaches biology at Monona Grove High School near Madison and has served as a BioNet area director, described several of her region's meetings.

At a session on prairie ecology, teachers examined the complex life webs in restored prairies on the Aldo Leopold Reserve. Seeds of prairie plants collected in the reserve were grown for use in school prairie restoration sites.

At another meeting, they experimented with ice nucleating bacteria that promote injurious ice crystal formation in plant leaves, flowers, and fruits. They explored the potential of replacing ice nucleators with bacteria that do not facilitate ice formation as a way of protecting plants from freezing injury.

In a workshop on DNA fingerprinting, teachers used polymerase chain reaction, frequently used in forensic identification, to sequence and "fingerprint" their own DNA.

The network holds a meeting at the end of the year in connection with the annual meeting of the Wisconsin Society of Science Teachers. And BioNet publishes an annual "BioNet Booklet" that highlights curricular activities presented at the regional BioNet meetings. The activities described are designed to be done easily in class with inexpensive and readily available materials.



Opportunities for you in Biology Education.
A compilation of funding, research, inservice programs
and other offerings for teachers

Education Opportunities for Teachers

in Biology and the Life Sciences

compiled by the Center for Biology Education

University of Wisconsin, 660 WARF Building, 610 North Walnut Street, Madison, WI 53705, [illegible]

The Center for Biology Education provides information on in-service training opportunities for teachers in Wisconsin and throughout the region.

For example, the 1994 booklet includes a lesson on the human sense of taste that requires only a blindfold, cups, straws, and a soft drink. In another, an enzyme simulation activity is presented that requires little more than paper and scissors.

Teachers developed an activity that illustrates how "ignorant" individual enzymes capable of carrying out only a single task can participate in a complex sequence of chemical steps. Different constructions are created from paper squares by cutting off or folding numbered corners of the square, puncturing the center of the square, and rotating the positions of the corners. Each construction is named as an enzyme with its own job, e.g., *punched-hexagon corner-3-foldase*. Students work (play) to match particular enzymes that demonstrate complex product processing. Most of the other lessons require only standard laboratory equipment.

Ms. Johnson, who has won a National Biology Teacher of the Year award, notes that the network provides more than information. It helps teachers overcome the isolation they may feel as teachers, particularly in rural areas, and also encourages them to try new approaches to teaching modern biology to students.

Another mini-grant helped Dr. James Lorman, Professor of Biology at Madison's Edgewood College, set up the Heron Network, a group of eight teachers, most of them elementary school teachers, who worked for a semester with Dr. Lorman and other university researchers. The university scientists acted as mentors, helping the teachers to develop a research and training agenda based on the ecosystem of a local watershed. The agenda was then used at the Heron Institute, a summer teacher training workshop at Edgewood for K–12 science teachers.

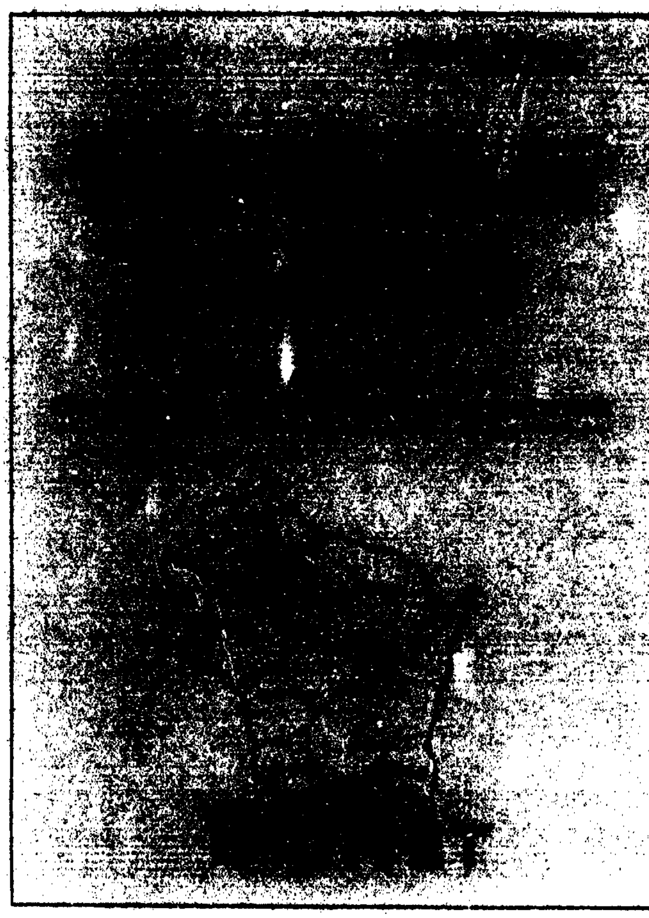
According to Dr. Lorman, the Heron Institute is modeling an approach that teachers can use in their classrooms with their students. Teachers develop the research question and the research agenda, then develop procedures that result in rigorous data.

During the 1994 Heron Institute, teachers completed projects on redwing blackbirds in local marshes, quantitative sampling of marsh vegetation, lake zooplankton, fish population, water quality measurement, and a combined project on climatology, hydrology, and soils in the local ecosystem.

"Some teachers have totally revised what they do in their classroom," says Lorman, describing the results of the Heron Network. "Rather than use textbooks, they're having students learn science by doing science and asking questions about their local environment."

The Center developed a similar project in Wisconsin's Kickapoo Valley, a 70-mile watershed in a depressed rural section that has suffered considerable environmental degradation. The project provides teachers from 10 schools in the area with inservice training in plant and environmental sciences, and they develop lesson plans and exercises based on their experiences while working on a real-world problem affecting their community.

Teachers are introduced to ways of teaching as student-based research both in and out of the classroom. Using Fast Plants as a model organism, students throughout the Kickapoo Valley



BioNet links Wisconsin high school biology teachers with the resources of local universities, colleges, government, and industry.

experimented with soil nutrition, water and atmosphere quality, and plant growth and seed production. Students developed their own questions and designed their own experiments.

Institute funds also support the Center's Bridging the Gap program, which brings teachers who would like to do more hands-on science together with university and other professional scientists who have an interest in precollege education. Each February, the Center holds a conference in Madison. The 1994 conference brought some 50 teachers together with 52 researchers from the University (including faculty, staff, and graduate students) plus about 20 researchers from private business and government agencies.

At the conference, the researchers give presentations on their work, offering the teachers the chance to take part in hands-on experiments and to discuss possible partnerships. This year's 18 topics included "Teaching HIV and Cancer to Children," "Hornworms Hatched on Transformed Tobacco," and "Prairie Restoration for School Sites."

Using Fast Plants for Genetics Teaching

Professor Williams, a plant scientist, originally developed fast-growing plants (rapid cycling brassicas) to speed his genetic research. He realized that these "fast plants" could help K–12 teachers bring hands-on plant science into classrooms by allowing students to do experiments and see change occurring quickly and often. Williams and others at the University set up the Wisconsin Fast Plants program, a network of teachers who develop and use instructional materials based on fast plants. In addition, some 1,500 scientists worldwide are now doing research on fast plants that WFP regularly converts into new classroom resources.

High school students in Lancaster, Pennsylvania, investigated the mutational effects of extraterrestrial radiation in pollen irradiation experiments on Columbia Space Shuttle 22. A group of 6th graders in San Bernardino, California, and their teacher, Robin Bernier, have investigated the function of hairs on fast plants by using genetic stocks with differing numbers of hairs. They have discovered that hairs are a deterrent to juvenile stages of the cabbage looper, a serious insect pest.

Many students across the United States are engaged in research on the genetics of quantitative traits such as seed yield and plant size. Fast plants are a popular organism for independent student science projects.

Fast-plant innovations and materials are disseminated to 25,000 teachers by computer networks, conferences, training workshops, and a regular newsletter. Many of these materials are used in the Center's mini-grants program, and other aspects of in-service teacher training.

Six teachers who went to Madison for training in February 1994 conducted a Fast Plants workshop for 30 elementary and secondary teachers. That spring, the teachers used Fast Plants with their students, and on May 11, CBE held a Fast Plants science fair at North Crawford, Wisconsin, involving some 135 students and their teachers.

Russell Gilbert, who teaches science at North Crawford Elementary School and has served as a teacher trainer, noted the wide variety of classroom applications of the Fast Plants model. He said that the simplicity of the materials, combined with the importance of the subject matter conveyed by the exercises, has attracted increasing numbers of teachers to the Fast Plants methodology.

Program Director

Paul H. Williams, Ph.D.
Professor, Department of Plant Pathology
Room 495, Russell Laboratories
University of Wisconsin–Madison
Linden Drive
Madison, WI 53706
(608) 262-6496
(608) 262-0014 (fax)

Institutional Profile

Total enrollment	39,128
Undergraduate enrollment	29,727
Number of faculty members	2,407
Endowment (millions)	$88
Annual budget (millions)	$920

Preparing Tomorrow's Science Teachers Oberlin College

Oberlin College is a private liberal arts institution in Oberlin, Ohio. In 1993 the Howard Hughes Medical Institute awarded the College $500,000 in support of (1) laboratory renovations and equipment acquisitions to expand and enhance teaching in areas such as general introductory biology, chemistry, and neuroscience; (2) summer laboratory experiences for students, including women and students from minority groups underrepresented in the sciences, and opportunities for students to discuss research at a colloquium with visiting scientists and present their results at regional or national conferences; and (3) a program to interest biology majors in science teaching by linking them with College faculty and with local high school teachers in developing instructional materials on specific biological topics to be presented by the students in high school classrooms.

How It Started

Oberlin used its 1988 grant largely for curriculum development. It is using the 1993 grant to interest undergraduate science students in precollege teaching by developing task force teams comprising an Oberlin College science faculty member, an Oberlin College student, and a master teacher from the Oberlin public school system. The project is directed by Dr. Dennison Smith, a professor of neuroscience and psychology.

The proposal for an outreach project grew out of Oberlin's desire to offer science students opportunities to participate in precollege science teaching, something they have had little opportunity to do since the college dropped its undergraduate and graduate education programs more than a decade ago. Until that time, Oberlin had been graduating up to 200 certified students per year. During the 1970s, shifts in career interests among Oberlin students and changes in Ohio's requirements for teacher certification precluded continuation of the program. But now, according to Dr. Smith, the outreach project "fits in nicely with the renewed student interest in teaching, and it is also consistent with a strong tradition of volunteerism at Oberlin."

Although Oberlin's school district is fairly small and semi-rural—it includes some 1,400 students in two elementary schools, a middle school, and high school—its enrollment is both racially and economically diverse. Thirty to thirty-five percent of its students are African American. Children whose parents are professors or other professionals share classrooms with children who are poor and disadvantaged.

The primary goal of the outreach project is to encourage Oberlin students majoring in one of the biomedical sciences to pursue science teaching as a career by giving them an opportunity for experience in a public school classroom. Anticipated ancillary benefits include improved science teaching in the local schools, creation of an avenue for Oberlin science faculty to help develop scientists and encourage science literacy at the precollege level, and development of a solid, cooperative relationship between the college and the local school system.

As First Proposed

Oberlin originally planned to support five teacher-initiated classroom projects for three years. The proposal to the Institute called for the teacher, the science student, and the faculty member to meet during the summer to work up each project scheduled to be delivered the following year. All three participants were to receive stipends to compensate for the time invested in the planning stage.

Once projects were proposed by the teachers in consultation with Professor Smith and deemed fundable, the related student positions would be announced. Student applicants would be chosen by a group of Oberlin science faculty based on their academic promise, science background, and articulated interest in teaching. Each student selected for the program would receive one to two hours of academic credit for successful participation. Creditworthiness would be determined by the faculty member and the supervising teacher.

According to Dr. Smith, the first teacher-faculty meetings were scheduled to take place in March 1994 so that students could be notified about opportunities prior to the April deadline for fall preregistration.

Lessons Learned: Different Kinds of Teachers

Professor Smith reports that working with the school system the first year required unanticipated patience and flexibility. While the overall plan for the outreach program remains intact, changing circumstances have forced some alterations in the original plan. "When we first planned this project, we thought that every teacher would have a clear idea of the kind of science unit or project they wished to implement in their classroom. We incorrectly assumed that insufficient funds accounted for the relative absence of more innovative projects in the schools. Instead, we found that although a large number of teachers wanted to upgrade their science curriculum, they simply did not have the appropriate background to do so."

"Because Oberlin's proposal was designed primarily to introduce students to classroom teaching, we abandoned the requirement that all classroom projects had to be developed *de novo*. Accordingly, we introduced teachers to some of the existing instructional material recently developed by the Lawrence Hall of Science at Berkeley (Full Option Science System—FOSS, Chemical Education for Public Understanding Program—CEPUP). Probably because such programs demand less time from teachers, the number of teacher applications has increased. Moreover, we felt that participating Oberlin students could get as much out of trouble-shooting one of these programs as they would from implementing a teacher-created program. In either case, the student will help the teacher prepare material for presentation and assist in its delivery to the students.

Six teachers of grades 1–8 will be funded in the coming year. "All they would need would be funds and input from, say, an undergraduate biology major," says Dr. Smith, "but we found that not all teachers are on the same level. There are a lot of teachers who would really like to put some interesting science things in their classrooms, but who often don't know what the best things would be and in some cases feel a little overwhelmed by coming up with an idea on their own."

Oberlin realized that such teachers would get more benefit from using innovative science programs and curricula that had already been prepared and tested in other classrooms. "We gathered up a bunch of hands-on programs that different institutions had put together—the state of New York, the state of Ohio, and a number from the Lawrence Livermore Labs." Three of the five schoolteachers involved in the outreach program preferred to use such prepared materials.

Two of the teachers did propose their own projects. One of them teaches in an open classroom environment and is very interested in developing a series of projects that combine arts and sciences. One of the projects this teacher chose integrates a discussion of the nature and properties of light with a discussion of the way artists use light. The other teacher is very interested in astronomy and hopes to use a kind of inflatable planetarium in her class that will illustrate different astronomical phenomena.

The differences in the teachers' approach led to some changes of procedure in the outreach project. Because they were not developing a brand new project, the three teachers who selected prepackaged programs did not need to have prolonged conversations with an Oberlin science faculty member.

"It was mostly a matter of just looking at the existing programs, making a plan for implementing one of them, then coming back and reviewing the plan," Dr. Smith says. This also meant there was less need to spend the Institute funds on stipends for the teacher and faculty member. As a result, Oberlin is considering diverting some of that money to paying for the prepackaged programs.

The differences among the teachers will also mean that the Oberlin students will have somewhat different roles in different classrooms. The two teachers who have developed projects of their own have a great deal of creative energy, but a limited science background. The student's role will be to help the teachers who use a prepackaged program to implement and expand it in the classroom. "I would hope the student will say, 'This is the way the packaged program does this, but we could try this and that instead,'" says Dr. Smith.

Lessons Learned: Communicating with Teachers

Changing circumstances led to another shift, as well. "We're admittedly about three months behind our original schedule," says Dr. Smith. The delay offers a lesson for other colleges planning to work with a local school district.

In 1993 Professor Smith had discussed the outreach project with the superintendent of Oberlin's schools, who was so enthusiastic he went to each of his schools and secured preliminary promises from teachers to participate. But the superintendent left the district in December 1993. It took the new superintendent time to familiarize himself with the program, and even longer for his office to announce the program to teachers. When the program was finally made known to the districts in late March and early April, almost no one signed up, according to Dr. Smith.

When Dr. Smith talked to teachers, he discovered that they felt they had not been given enough prior notice about the outreach program, and they had not been clearly informed about what participation involved. By the time this problem became apparent, it was too late to start the recruitment process for Oberlin students in May. "If I learned one thing," Dr. Smith says, "it was, don't let the administrators do the communication with the teachers. Go over there and do it yourself."

Because of the delay, the meetings between Oberlin faculty and the sch ol teachers took place in late June, and the students were not told about the opportunity until they returned to complete registration in September. Five were then chosen to take part in the program.

Oberlin Students in the Classroom

The exact role each Oberlin student will play in the classroom will have to be negotiated between the teacher and the student, Dr. Smith says. "My experience with teachers is that some want almost entire control of what this person is going to be doing, while others are more relaxed," he adds. In general, the Oberlin students will not function as student teachers, taking over an entire class or an entire subject for the teacher. "But we've ensured that the Oberlin students will be in on the implementation of the science teaching," he says. In particular, the Oberlin students will help with the hands-on science activities that will be a part of the projects in all five of the classrooms.

Oberlin science faculty members will meet regularly with the science majors, once they are in the precollege classroom, to discuss problems, challenges, and ways to improve the student's contribution to the science activity in the classroom.

Dr. Smith also emphasizes that the last thing the outreach program wants to convey is that "we're going in as experts telling these teachers how to teach." The program will stress "mutual respect."

"The teachers are professionals who know what they are doing in their domain," he says. "We're trying to find out what they need and want. We can be resources, offering them some of the science they may not have."

The Future

If the outreach project proves successful, Oberlin hopes to continue a working relationship, with the school system using its own resources after the Institute grant expires. "Once the project is up and running, the kinds of things we're doing do not really require a huge amount of money. The costs would be such that we could continue the project on our own. Our intent is to establish a long-term connection with the school system and over the years continue to encourage good science students to think about teaching."

Program Director

David H. Benzing, Ph.D.
Robert S. Danforth Professor of Biology
Department of Biology
Kettering Hall of Science
Oberlin College
Oberlin, OH 44074
(216) 775-8461 or 8120
(216) 775-8960 (fax)

Institutional Profile

Total enrollment	2,725
Undergraduate enrollment	2,700
Number of faculty members	235
Endowment (millions)	$280
Annual budget (millions)	$73

Preparing Tomorrow's Science Teachers
State University of New York at Binghamton

The State University of New York at Binghamton is a public doctorate-granting institution. In 1992 the Howard Hughes Medical Institute awarded Binghamton $1,500,000 to support (1) activities to attract and retain students in the sciences, including underrepresented minority students, to include work in laboratories of biology, chemistry, and physics faculty during the summer and academic year; (2) revision of introductory courses to emphasize collaborative research among teams of students working on scientific problems; (3) acquisition of new laboratory equipment and faculty development to implement the curriculum enhancements; and (4) research experiences in University biology, chemistry, and physics laboratories for high school students from New York City and summer workshops in modern biology for teachers from New York State junior high and high schools.

The Teaching Scholars Program

In 1992, with HHMI support, the faculty of the Department of Biological Sciences at the State University of New York at Binghamton established a Teaching Scholars Program for upper-level undergraduates. For six weeks in the summer, 6–12 students, most of them seniors, receive a stipend for participation in an intensive laboratory exercise run-through and receive other training as well. During the academic year, they help to instruct first- and second-year students. The undergraduate teaching scholars work with graduate teaching assistants and help guide the lower-division students through a series of new researchlike modules that are part of their introductory laboratory classes in biology.

The teaching scholars greatly benefit from this opportunity to impart practical lessons in biology to lower-division students and provide them with guidance by trouble-shooting for this challenging series of research-oriented laboratory exercises, said Dr. Anna Tan-Wilson, Professor, Department of Biological Sciences, and HHMI program director. In addition, the teaching scholars say that these laboratory teaching experiences serve to reinforce their own knowledge and understanding of experimental biology. They often need to review the subject during the course of the year, and thus they learn it in greater depth than when they took the same course a year or so earlier.

Program Goals

The Teaching Scholars Program is neither a substitute for formal training in educational skills, nor is it intended to turn biology majors away from a career track in research or medicine. However, it does give partici-

As part of the Teaching Scholars Program, Samuel Washington (left) and Lincoln Cox (seated) discuss the results of an electrophoresis gel run by Pierre Frederique (right) for use in an introductory biology course. This program helps stimulate student interest in teaching careers by providing opportunities for science teaching and materials development.

DAVID TUTTLE

pants a real taste for what teaching is like, and several of them plan to pursue teaching careers or make teaching an important part of their future activities.

"The teaching scholars really get below the surface and build their [own] self-confidence. They also tend to choose more difficult electives in biology as a result," Dr. Tan-Wilson noted. "After teaching the laboratory course, they really feel like they own the subject material. Some of them also do research projects at the same time or during the following year as seniors."

For example, Leah Mechanic, a teaching scholar during the 1993–1994 academic year, also participated in the Research Scholars Program, which gives students the opportunity to work on a research project. Ms. Mechanic's work centered on the activity of phenoloxidase in the Verson gland of the tobacco hornbeam. The enzyme is involved in various insect processes such as melanization and wound repair. After working out optimal conditions for gel electrophoresis of the enzyme, she discovered that the gland produced a form of the enzyme that differed from the forms produced in other tissues. The form appeared after pupal commitment and during pupal molting, findings consistent with the idea that the gene for this unique form of the enzyme is regulated by the hormone ecdysone.

"And there is another benefit for their younger peers who are taking these biology laboratory courses," Dr. Tan-Wilson added. "The first- and second-year students see different minority teaching scholars, which impresses the younger students and helps raise their morale in general."

Students Helping Students

"I was not only helping my students as a teaching assistant in their biology lab class, I was also helping them as a peer pre-med adviser," said former teaching scholar Joanne Holder, an African American who served as a role model for other minority women. "The students saw in me someone who had successfully completed the college pre-med grind and who would be attending the University of Pennsylvania Medical School. For me this was a unique opportunity to give something back to the students. This program also allows you to develop two important skills—helping individuals and interacting with others."

The Teaching Scholars Program arose in part out of necessity. Faculty members in biology had been gradually improving the modules for the undergraduate laboratory courses in biology, making them more challenging for both the students and the graduate teaching assistants, who are in charge of the modules. Not only were the experiments modernized, they also were redesigned to more closely resemble research situations rather than cookbook exercises.

For instance, in one exercise, students learn how to extract DNA from bacterial cells and subject the macromolecules to restriction enzyme digestion and subsequent electrophoretic analysis on gels. However, instead of following a fully planned set of analytic steps on preselected samples, students are asked first to transform bacterial cells with DNA containing a gene encoding antibiotic resistance and then to analyze the DNA differences between the initial bacterial sample and the antibiotic-resistant bacterial strains that the students have produced.

When first- and second-year students conduct such experiments, they frequently need both technical help and sophisticated answers to their questions in order to fully understand what they are doing, and the teaching scholars play important roles in meeting both needs.

The introductory laboratory classes were revised so that students got a sense of excite-

Teaching Scholars Anna Chan and Ann Kim (left to right) test a procedure for the transformation of bacteria, an adaptation of a Cold Spring Harbor Laboratory course, DNA Science, for the SUNY–Binghamton introductory biology laboratory.

DAVID LITTLE

ment from discovery and a sense of accomplishment from planning and carrying out short investigative segments on their own. Moreover, in adjusting the procedures and conditions to be followed in those exercises, the teaching scholars come to understand them very thoroughly.

They prepare for this teaching challenge by working in the laboratory for six weeks during their summer training. They run through the laboratory course modules and fine-tune them under the guidance of Professor Herbert Posner, director of the Biology Department's Undergraduate Program.

During the summer of 1994, teaching scholar Farzana Kapadia modified an experiment on light-induced proton gradients in chloroplasts. She developed methods for isolating chloroplasts with only one centrifugation step instead of two. Ms. Kapadia then determined the appropriate ratio between concentration of chloroplasts and concentrations of the artificial electron acceptor PMS for obtaining maximum pH change without damage to the chloroplasts. As a result of her work, students in the introductory biology laboratory can now successfully complete this experiment in a three-hour period.

Other members of the biology faculty who are directly involved in teaching the introductory laboratory course agree that the participation of the teaching scholars has been an asset. Noted Dr. Julian Shepherd, who taught this course in the spring 1994 semester, "The student scholars had such a thorough grounding in their understanding and experience with the experiments that their presence in the classroom was of tremendous importance."

Voices of Experience

"Being a teaching scholar allowed me to work in a classroom setting and gave me the opportunity to explore teaching as a possible career path," says Kim Marie Bieber, a 1993–1994 teaching scholar. "I am thinking of getting my teaching certification in graduate school."

Robert Schwartz, who was a teaching scholar in 1992, plans to join Teach for America, a program that typically places college graduates in inner-city or rural high schools, where they have first-hand exposure to some of the problems now facing public school educators throughout the United States.

"I have decided to pursue a career in teaching because I enjoy working with young people and feel education is an ongoing learning process for teachers," says Karen Blodgett, another 1992 teaching scholar, who is working toward a master's degree in science education. "I think the Teaching Scholars Program really prepares students to teach a laboratory by [giving them] hands-on experiences."

Program Director

Anna Tan-Wilson, Ph.D.
Professor
Department of Biological Sciences
State University of New York at Binghamton
Binghamton, NY 13902-6000
(607) 777-2651
(607) 777-6521 (fax)
ANNATAN@BINGVAXA.CC.BINGHAMTON.EDU
(Internet)

Institutional Profile

Total enrollment	11,295
Undergraduate enrollment	8,892
Number of faculty members	523
Endowment (millions)	$8
Annual budget (millions)	$84

Preparing Tomorrow's Science Teachers
University of Nebraska–Lincoln

The University of Nebraska–Lincoln is a public research institution. In 1992 the Howard Hughes Medical Institute awarded the University $1,000,000 to support (1) a program to enhance the recruitment and training of elementary and secondary school teachers in the sciences, with new courses in contemporary biology developed jointly by the School of Biological Sciences and the Teachers College, in-service minicourses in scientific fields, and other activities; and (2) involvement of undergraduates, including women and underrepresented minority students, in research early in their academic careers through new research-oriented courses, laboratory facilities, and equipment.

New Courses for Future Educators

The focus of the HHMI program in the biological sciences at the University of Nebraska–Lincoln has been the development of Biology 295, a biology class for elementary education majors. The course was developed during the 1992–1993 school year and implemented in the 1993–1994 school year. This hands-on course was team taught by Jim Landon, a former high school teacher from Seward, Nebraska, and associate director of HHMI-supported precollege programs at the University, by Kathy Jacobitz, a 7th–12th-grade science teacher at Henderson Community School, and by Dave Crowther, an instructor in Teachers College and former elementary school teacher in Utah. Dr. Eric Davies, Professor, School of Biological Sciences, and HHMI program director, has had enthusiastic feedback from the students. One called it the "best course ever for future teachers."

A middle-school genetics project, "Why Do You Have Your Grandmother's Nose?", developed by Nebraska teachers Sue Koba and Frank Tworek, was modified for Bio 295. The project explores many issues of human diversity through hands-on activities, laboratory experiments, creative writing projects, and discussions.

Margaret Sievers, Chief Adviser for the Teachers College at the University, discovered an unusual attribute among students who wanted to enroll in Bio 295. The majority of them stated that they "hated science." After completing the four-month training program, 95 percent had completely changed their attitude and, for the first time, were enjoying learning science.

One of the Bio 295 students commented, "Doing science is better than memorizing science." Another wrote, "This class has given me the opportunity to concentrate on the meaning of science and, at the same time, learn ways to teach it to my students that will spark their knowledge and interest."

Dr. L. James Walter, Chair of the Center for Curriculum and Instruction for Elementary/Secondary Education, stated, "If we could get courses in physics, chemistry, and earth sciences that have foci similar to that found in Biology 295, we would produce a generation of elementary education teachers who have a great impact on elementary education in a short time."

Coordinating the programs initiated by HHMI funding has been a challenging task for Dr. Davies. Although the focus has been on the development of new curricular and training methods in the biological sciences, other departments have benefited from this work also. Dr. A. F. Starace, Chairman of the Physics Department, and Dr. Paul Kelter, an associate professor in the Chemistry Department and Co-PI of Operation Chemistry, are actively encouraging the development of hands-on science education in their respective fields.

Mr. Crowther's doctoral dissertation will involve a long-term project to assess the success of courses such as Bio 295 and other methods for teaching hands-on science. He is developing a tracking system that will help evaluate these programs as students graduate and move on to their individual teaching assignments.

Technology in the Classroom

A major innovation at the University is the total refurbishing of the Henzlik Hall Multimedia Auditorium, funded both by the Institute and the University. The auditorium contains state-of-the-art technology, including Macintosh and PC computers, an image-scanning device, a variety of software packages, laser disks, VCRs, tape players, a projection television, a modern audio system, and a trinocular microscope with large screen projection, as well as more traditional science laboratory equipment. It is used for teaching large classes such as Introductory Biology, Zoology, Anatomy and Physiology, and Genetics.

Physics for Biologists Lab

The Physics for Biologists laboratory course has been totally redesigned using Institute funding. The laboratory was introduced to teachers and students through multimedia tutorials. Participants commented that "tutorials were helpful in learning the material" and "the laser disk with the computer was the part that made it very pertinent to what we were learning."

In fact, this is exactly what is being done at the University by Dr. Robert G. Fuller, a physics professor and recipient of the Robert A. Millikan Medal (who is also working with Dr. Davies's

Students examine a crayfish in the University of Nebraska–Lincoln's Biology 295, a hands-on, laboratory-based biology class for elementary education majors.

group to develop a course in hands-on physics for elementary education majors). The Physics for Biologists lab includes multimedia- and microcomputer-based laboratory experiments. In the process of developing materials for this laboratory, K–12 curriculum materials are also being produced. These materials will also be used to train teachers in elementary science education courses.

Vicky Plano Clark (laboratory manager) and Christopher Moore (research associate), both in the Department of Physics and Astronomy, stated that today's students respond positively to courses with a video component. They have also developed a workshop entitled "New Trends in Physics Teaching," which incorporates advanced technology in teaching a hands-on approach to training elementary- through college-level physics students.

Outreach to Educators

In 1994, University faculty members presented a number of workshops throughout the United States. These workshops were based on their experiences in fusing physics and biology teaching techniques that incorporate multimedia and hands-on laboratory instruction. Workshops developed through HHMI funding include "Using Digital Images to Assess Student Performance" and "Using Multimedia Labs to Teach Optical Concepts to College Students."

Dr. Davies believes that the Institute can play a central role in the development of unique collaborations among educators. Several of the faculty members traveled to Pittsburgh for the American Association of Higher Education meetings, where they shared information on their school collaboration experiences.

Many of these programs have been widely disseminated. There has been some press coverage of the videotaped programs that have been produced. A program sold at a Cornhusker football game during the fall semester featured an article about the HHMI course.

Activities for Precollege Educators

Exciting activities for K–12 educators have been developed at the University with HHMI funding. Seminars, summer workshops, collaborative projects with the Teachers College, and outdoor nature projects at sites throughout the state are some of the new developments in collaborative hands-on science education for teachers. With funding from the Institute and several other sources, a K–12 summer program has been developed to retrain educators. This program is coordinated by Mr. Landon.

Two other exciting projects are headed by Ms. Jacobitz, who won the Christa McAuliffe award for innovative science teaching. One, a National Wetlands unit, was developed by Ms. Jacobitz, Mr. Landon, and Sharon Bishop, a local teacher. This unit allowed teachers and students in 23 schools in 16 states to investigate the health and diversity of wetlands across the United States. The experimental design and data analysis were shared via telecommunications nationwide and with the national EPA officer in Washington, D.C.

The second unit, the Radon project, involved the University's Department of Biochemistry and Teachers College, the Nebraska Department of Health, and many Nebraska schools. A questionnaire about radon was developed by students, radon levels were measured in over 2,000 locations, and students communicated their results through Internet.

These projects involved active research and learning by Nebraska high school students and are connected to the goals of Project 2061 and the Nebraska Frameworks, a document reviewing teacher training and certification throughout the state.

Program Director

Eric Davies, Ph.D.
Professor, School of Biological Sciences
348 Manter Hall
University of Nebraska–Lincoln
Lincoln NE 68588-0118
(402) 472-3202
(402) 472-2083 (fax)
EDAVIES@UNL.EDU (Bitnet)

Institutional Profile

Total enrollment	21,776
Undergraduate enrollment	18,199
Number of faculty members	1,376
Endowment (millions)	\$2*
Annual budget (millions)	\$225

*income

Arizona State University

Arizona State University is a public research institution in Tempe, Arizona. In 1992 the Howard Hughes Medical Institute awarded the University $1,500,000 to support (1) a program to attract and retain students in the sciences, including women and underrepresented minorities, through revision of the core biology curriculum to emphasize student experimentation and discovery, with development of new instructional materials and scientific equipment; (2) faculty development to implement the new curriculum, with participation of community college faculty and high school teachers in the curricular revision; and (3) enhanced undergraduate research during the summer and academic year, with introductory seminars on research concepts and techniques, travel to scientific meetings, and colloquia to present research.

A Working Relationship

During the summer of 1994, Arizona State University sponsored a monthlong intensive summer workshop for Maricopa County Community College District faculty. This was one of a series of Teaching Strategies Workshops designed to aid life sciences faculty to undertake reforms in the biology curriculum by stressing critical inquiry rather than rote memorization. For the first time, the workshop was directed to faculty who teach introductory biology at ASU and local community colleges. Ten of the 14 participants whose stipends were supported by the HHMI grant were from community colleges. The others were Arizona State University faculty who also teach introductory biology.

Almost 40 percent of each Arizona State graduating class are former community college students, who usually transfer after their sophomore year. To ensure that these students have experiences comparable to their University counterparts and receive transfer credits, Arizona State University and the Maricopa County Community College District have formal agreements in place to teach similar material in the two-semester introductory courses required of biology majors. To underscore the similarity, the introductory sequences at the University and neighboring community colleges have the same course titles and numbers. Recognizing this strong interdependence, Dr. James Collins, Chairman of Zoology and HHMI program director at Arizona State University, observed, "It is incumbent upon us to incorporate community college faculty members in our attempts at reforming our core curriculum."

With 40,000 students, Arizona State University is situated in the Phoenix metropolitan area,

During the 1994 Teaching Strategies Workshop at Arizona State University, Dr. Karen Conzelman, Glendale Community College, participates in a laboratory exercise designed to foster critical inquiry.

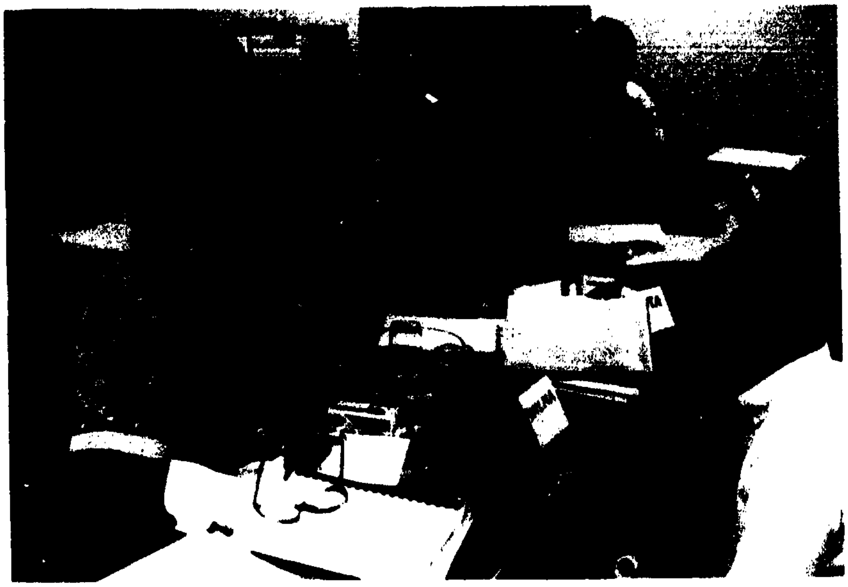
which includes significant numbers of Hispanic, Native American, and black students. Since introductory courses in life sciences often have hundreds of students, the 10 community college faculty taking the Teaching Strategies Workshop may reach over 1,000 students each year.

Word of mouth from last year's participants was so influential that very little outreach was needed beyond a formal letter from the University to all the chairmen of biology or life sciences in the Maricopa County Community College District. The University was able to accommodate all 10 faculty, including 2 department chairs, who applied from 9 of the 14 community colleges. "We were especially eager to have the department chairs participate because their leadership would help set the tone at their community colleges," said Dr. Steven Rissing, Professor of Zoology, who managed the recruitment process and took the course in the summer of 1994.

Teaching Strategies Workshop

The Teaching Strategies Workshop is guided by the philosophy that science should be taught the way it is done. Its practical goal is to have the participants develop laboratory exercises that they can use to complement introductory lectures. Instruction in the workshop is aimed at helping faculty take advantage of the learning cycle method of teaching, a method that fosters critical thinking as students gather data in a descriptive fashion or embark on a controlled way of testing hypotheses. True to its philosophy, the

Dr. Anton Lawson (kneeling) listens as Dr. Wilma Patterson (left), South Mountain College, and Anita Herl-Peterson, Phoenix College, review hypotheses to explain the burning candle experiment during the 1994 Teaching Strategies Workshop. Also shown in the photograph (background, left to right) are John Weser, Mesa Community College, Clarice Weide, Gateway Community College, Dr. Linda Wegener, Life Science Chair, Mesa Community College, and Terry Ponder, Paradise Valley Community College.



workshop is guided by the learning cycle to inculcate scientific concepts and thinking skills.

The first day of the workshop captures the theme that science should be taught the way it is done. With 10 simple materials, the workshop instructor stimulates curiosity by presenting a burning candle, held upright in a small piece of clay, in a pan of water. Soon after the burning candle is covered with a cylir ler that is open at the bottom and closed at the top, the flame disappears and water rushes into the cylinder.

By refraining from explaining the physical laws governing these observations, the instructor encourages the participants to develop hypotheses to explain what happened: Why did the water rise? Why did it rise after the flame went out? And instead of immediately responding, the instructor has the participants develop testable means of confirming or discarding their hypotheses.

The participants' struggle to understand physical principles is an important ingredient of the learning cycle. In the candle burning experiment, the most common explanations offered by the participants are incorrect. Contrary to intuition, a vacuum does not "suck in" water from the outside.

Only through testing various hypotheses can participants acquire a first-hand understanding of combustion and air pressure and learn that the water rise is due to expansion and contraction of heated and cooled air. Last year, one faculty member wrote in h r evaluation, "I finally understand why some of my students 'just don't get it' and why certain concepts seem almost impossible for certain students to learn."

The challenge of the first day's exercise is followed by an explanation of the workshop's backdrop—the use of the learning cycle to teach scientific concepts and thinking skills. In the ensuing weeks the participants work in teams to develop new laboratory exercises for use in their introductory courses. Upon completion of the new exercises, the teams present their ideas to the other participants, who are encouraged to provide feedback. According to Dr. Anton Lawson, Professor of Zoology and workshop instructor, "The feedback component of the workshop is essential in helping each group refine its laboratory exercise, and it promotes greater creativity."

Through feedback from fellow participants in the summer of 1993, Dr. W. Dennis Clark, an associate professor in the University's Department of Botany, began to revamp the entire laboratory component of his introductory course for nonmajors. He transformed each laboratory exercise into an exploration incorporating the learning cycle. "I set the tone for each lab by converting the title of the exercise into a question, such as How are plants classified? and Why do plant characteristics vary?" he said.

While a few students were unable to use the learning cycle to their advantage, he found that most students responded very favorably to the new approach. Dr. Clark hopes that his innovations will be adapted by community college faculty who teach the same introductory course.

John Weser teaches biology at Mesa Community College. He received credit toward his doctorate by participating in the 1994 summer workshop. Nearby Mesa Community College, which serves 30,000 students, is a chief source of students to the University. Mr. Weser began the workshop with the hope that he could "apply right away what I learn and encourage other faculty to do so....I want to develop labs where students are learning from each other instead of being talked at."

Program Director

James P. Collins, Ph.D.
Professor and Chair, Department of Zoology
Arizona State University
Tempe, AZ 85287-1501
(602) 965-3571
(602) 965-2519 (fax)
ICJYC@ASUACAD (Bitnet)

Institutional Profile

Total enrollment	41,250
Undergraduate enrollment	30,178
Number of faculty members	1,614
Endowment (millions)	$43
Annual budget (millions)	$668

City University of New York City College

City College of the City University of New York is a public comprehensive university. In 1993 the Institute awarded City College an additional $650,000 in support of (1) programs of student research and broadening access for students that include the following activities: freshman research preparation and participation, upper-division research, and various activities to broaden student access to the sciences; (2) outreach programs, particularly for women and underrepresented minorities, to include such activities as research experiences, counseling, and science career information for high school students, summer research or academic preparation for prefreshmen, and a summer transfer program for community college students; and (3) laboratory instrumentation for cell and molecular biology courses and biology and chemistry modules.

Easing the Transition

A major effort is being made to help ease the transition of transfer students from two-year community colleges into the City College program. Dr. Joseph Griswold of the Department of Biology directs the summer science course for transfer students. The objective of the course is to make the transition from community colleges to senior college easier and more successful for students who have declared their intention to pursue a major in biology or chemistry.

Specifically, the summer course helps students with their social adjustment to the college environment, and their academic adjustment to rigorous intermediate-level courses in biology and chemistry. To accomplish these objectives, students broaden and enrich their backgrounds in the content areas and improve their science learning skills. They have opportunities to learn about the college campus and other student services available to them, and to interact informally with one another, with upperclassmen in their majors, and with faculty mentors. In addition, students complete their fall advisement and registration by the end of the course.

Recruiting transfer students was a joint effort by City College and community college faculty and counselors, coordinated by Dr. Robert Goode. One community college professor uses a college database to identify candidates, and Dr. Goode and Dr. Griswold visit the community colleges and are in frequent phone contact with counselors at those locations.

Fourteen students from four community colleges participated in the Hughes Transfer Course, held for three weeks in June 1994. Of these, 12 were minority students and 8 were women, of whom 7 were minorities. Students attended lectures, conduct-

Community college students learning computer analysis techniques in the Summer Transfer Program. Standing left to right, Dr. Henry Hermo, Bronx Community College, Chris Thompson, City College student leader, and Susan Ratner, City College student leader. Seated rear to front, community college students Tarciscio Herrera, Collin Dalrymple, Marie Edmond, Colin Grey, and Carline Vilfort.

ed experiments, participated in workshops that focused on writing scientific reports and solving problems, and worked on improving computer skills important for doing science.

Students attended classes from 9 a.m. to 4 p.m. Monday through Thursday, and from 9 a.m. to 12:30 on Fridays. Two days per week were devoted to learning sessions in biology, two days to chemistry, and one day to testing and competitions. On Fridays, the students reviewed their week's work, took individual quizzes, worked on team problems, and participated in skill relays and a quiz bowl. They were organized into three teams, each led by an upperclassman. Points were awarded for attendance, participation, quiz scores, the quiz bowl competitions, and grades on scientific reports and homework assignments.

Special events included an electron microscopy demonstration, a roundtable discussion about opportunities in science at City College, and a tour of the Science Building. Sessions offering admission and registration assistance were also part of the schedule.

The staff included faculty members in biology and chemistry from City College, Bronx Community College, and Borough of Manhattan Community College. Technical support was provided by college laboratory technicians in the biology and chemistry departments. Critical to the success of the summer course were three specially

Maria Alvarado conducts an experiment as part of the Summer Transfer Program.

selected upperclassmen who functioned as team leaders. These leaders attended all labs with the transfer students and led the workshops. They were an invaluable source of information.

Evaluation of the course was developed under the direction of an outside consultant. Various instruments and measurements were used, including pre- and post-course self reports by the students; pre- and post-test problems in biology and chemistry; and a pre- and post-course evaluation completed by the student leaders, as well as quiz scores, and grades on scientific reports and homework assignments.

"Students in the program," according to Dr. Sharon Cosloy, Professor and Chairman of the Department of Biology and HHMI program director, "worked hard, showed good enthusiasm, and did well overall in the quizzes and homework assignments." New activities in the program included the production of poster papers by student teams, instruction and practice in using software needed to do word processing, charting, statistical analysis, and simulations in chemistry.

In their end-course evaluations, students rated the course as very valuable for many reasons, e.g., learning to solve problems in biology and chemistry; learning to run experiments, organize data, and write scientific papers; learning the value of group study; and learning about the rigors of senior science courses.

Students commented that the most important aspects of the course were "how to write a scientific paper and to work in a group" and "to be able to familiarize myself with the use of MATHCAD and also graphing on computers." When asked about the strengths of the program, one student wrote, "Good instructors and faculty to teach their subjects, good coordination and environment." Another wrote that the course "prepared students very well to deal with the pressure they will encounter at City College." The most common complaint was that the course was too short.

Dr. Millicent Roth directs "The Freshman Year," which is part of the College's development and retention program. It addresses the inability of many underprepared students to complete the introductory courses. Of the 100 participants, 80 were minority students and 50 were women.

A major component of the program is the science preparation course, which includes a weekly counseling seminar. The course runs four hours per week and provides one credit. As the students develop problem-solving skills in science, they also develop self-awareness that enables them to direct and control their academic lives.

A counseling seminar, which is incorporated directly into the science curriculum, is designed to promote the students' ability to monitor, evaluate, and adjust their skills to achieve their academic and personal goals; to manage their academic experiences; and to assess their progress.

The science curriculum itself is divided into cycles, each built around a specific topic, which provide laboratory experiments, data analysis, problem sets, reviews, and a quiz. Tutorial workshops led by students focus on problem sets and provide experience in working through problem-solving strategies.

Four sections of the prep courses were offered in 1993–1994. Because of the success of the science course–counseling seminar package, the program has been accepted as part of the regular science curriculum. The program has also been accepted into the National Diffusion Network of the United States Department of Education, with facilitators in every state, who disseminate the methods and results of the members' projects.

The projects developed under a 1989 grant from the Institute continue to be successful in recruiting students and in retaining them by providing workshops, support systems, counseling, and tutoring. These projects also help to broaden students' appreciation of possible careers in science and train them for working in biological and biomedical sciences.

At City College, the HHMI projects are coordinated with others across many disciplines. A continuing pool of well-prepared students is being created. The program director believes that the success of this program is "due to the collegial atmosphere among faculty, staff, and students, which allows us to work together and stimulates the programs to grow and flourish."

Program Director

Sharon Cosloy, Ph.D.
Professor and Chairman, Department of Biology
City University of New York City College
138th Street and Convent Avenue
New York, NY 10031
(212) 650-6584
(212) 650-8585 (fax)

Institutional Profile

Total enrollment	14,892
Undergraduate enrollment	11,700
Number of faculty members	592
Endowment (millions)	$27
Annual budget (millions)	$94

Programs for Community College Faculty and Students
University of California–Davis

The University of California–Davis is a public research institution. In 1989 the Howard Hughes Medical Institute awarded the University $1,200,000 to (1) excite the interest of underrepresented minority students in biology and provide the foundation for their academic success with an enriched curriculum and research laboratory opportunities in their freshman and sophomore years; (2) develop an integrated introductory curriculum in biology and acquire laboratory equipment; and (3) expand links with community colleges to encourage transfer and assist with student, faculty, and curricular development.

The University Partnership Program

With HHMI support, faculty members at the University of California–Davis are taking steps to foster closer relationships with neighboring community colleges. Because so many UCDavis students take their lower-division science courses at these colleges, the University Partnership Program was established to assure that transfer students are appropriately prepared for their university course work in biology and other subjects.

"This issue of parity is particularly critical in the biological sciences, where in some instances the fast pace of change and the cost of equipping laboratories may make it difficult for the community colleges to maintain the kind of education necessary for the successful transition of their students to the university," said Dr. Merna Villarejo, Associate Dean of the Division of Biological Sciences and HHMI program director. At the center of the partnership program is the opportunity for community college faculty to spend a sabbatical semester on the Davis campus as HHMI teaching fellows.

This respite from their heavy teaching duties provides an opportunity for intellectual renewal and involvement in introductory biology at the university level. When the teaching fellows go back to their schools and update their biology courses, these changes also benefit their students, reducing the so-called transfer shock that occurs when students are ill-prepared for more sophisticated science courses at the university level.

Students also benefit from the improved relationships between faculty members at the University and the community colleges, which helps to overcome a misperception that UCDavis is a cold and arrogant place. So far, faculty members from three institutions in central California—Sacramento City College, Sierra College, and Yuba College—have participated in the partnership program, with very positive results.

The Sacramento City College Partnership

The Sacramento City College experience has been the most extensive, according to Dr. Villarejo. Over several years, most of the members of its biology department have spent up to two quarters on sabbatical at the Davis campus. Some of this time was spent in meetings with the dean and with faculty members to discuss how to derive maximum benefit from the sabbatical program. One goal was to revise the community college biology curriculum so that its introductory courses would articulate better with upper-division courses taught at the University.

Another goal was to enable the teaching fellows to decide which courses they would like to audit and what other intellectual interests they would like to pursue during their stay on the campus. One requirement was that they attend lectures of the introductory biology course that corresponded to their own area of teaching responsibility. Beyond the initial requirement, all five participants took different courses because each followed a separate subdiscipline and had somewhat different academic plans. Some helped teach laboratory sections for the introductory biology course to familiarize themselves with the new techniques and equipment used at the University.

These experiences proved especially useful for the visiting biologists, who began to update their own laboratory courses once they returned to their usual teaching duties, said Dr. Ken Naganuma, Chair of Biology at Sacramento Community College. "The first faculty member who came back said that we needed to re-do our cell biology course. So we've made it much more molecular in emphasis. In the laboratory, our students now begin handling DNA right away—doing micropipetting, gel electrophoresis, and bacterial transformations. And this means the students can also get jobs and be competitive in the marketplace," he says. "They love it!"

According to Dr. Naganuma, the biology faculty members have benefited in several ways. Some had not taken sabbatical leave for decades. Dr. Naganuma noted that they came back from their sabbaticals supercharged and really enthusiastic about their work—with significant impact on their students.

Other Partnerships

Other community colleges that participated in the program report similar benefits. Dr. Rita Hoots, who teaches biology at Yuba College and spent sabbatical time at the University in 1991, said that attending courses there helped her "integrate new data ... and focus the directions that I should take in preparing students to transfer to the university. Teachers need such opportunities to expand their understanding of current trends."

The university plans to extend its initial concept to more distant community colleges. Dr. Edward Garrison, an anthropologist and Professor of Biology at the Navajo Community College, Shiprock, New Mexico, will spend the winter and spring quarters of the 1994–1995 academic year on the University campus. The Navajo Community College belongs to a set of isolated tribal community colleges that usually have only one biology instructor and no funds for continuing education. Dr. Garrison, who teaches all the biology courses at his college, is expected to learn more cutting-edge biology at the University. The experience is seen as a potential model for partnerships between other universities and their neighboring tribal community colleges.

"My focus will be on acquiring enhanced laboratory skills for the core biology courses in our program at Navajo Community College," Dr. Garrison said. "We need the technical skills and experience in working with new and different laboratory equipment as the basis for an informed grant proposal." Dr. Garrison added that chronic shortages of funds have precluded giving sabbatical leave to the faculty. "The Native American students at the Shiprock campus will concretely benefit from my opportunity to become re-energized and re-excited about biology while I'm on sabbatical at Davis," he said.

Program Director

Merna Villarejo, Ph.D.
Professor of Biochemistry and Microbiology
Section of Molecular and Cellular Biology
Division of Biological Sciences
University of California–Davis
Davis, CA 95616
(916) 752-6281
(916) 752-3085 (fax)
MRVILLAREJO@UCDAVIS.EDU (Internet)

Institutional Profile

Total enrollment	22,889
Undergraduate enrollment	17,521
Number of faculty members	1,318
Endowment (millions)	$60
Annual budget (millions)	$995

The Role of Educational Technology in Broadening Access to Science

Educational Technology: Supplementing Laboratory Instruction

Beloit College, 142
Harvard University, 148
University of Puerto Rico Mayaguez Campus, 152

164

Educational Technology: Supplementing Laboratory Instruction Beloit College

Beloit College is a private liberal arts institution in Beloit, Wisconsin. In 1991 the Howard Hughes Medical Institute awarded the College $650,000 to support (1) laboratory research opportunities for undergraduates, particularly introductory students; (2) revision of the introductory curricula in biology, chemistry, physics, and calculus to emphasize laboratory research and scientific discovery; (3) special activities such as workshops and classes for science teachers and 6th–12th-grade students in Wisconsin and Illinois, designed to stimulate student interest in the sciences; (4) summer research opportunities for students from other institutions, especially those enrolling significant numbers of underrepresented minority students; and (5) summer workshops for local high school science teachers, providing research opportunities and exposure to new science teaching techniques such as using interactive biology computer simulations.

Developing New Approaches to Science Education

Like many colleges and universities, Beloit College has found that student interest in science often flags at the introductory level, when students take their initial courses in biology, chemistry, physics, and calculus. In many cases, capable students become discouraged when they fall behind in their scientific work and are never able to catch up. These students may have begun college with plans to become scientists or physicians, but their first experiences with college-level science turn them away from a potentially productive career.

At Beloit College, the science departments have been focusing their efforts to provide students, especially those in their freshman and sophomore years, with the tools to overcome the initial challenges they face in their science courses and go on to complete upper-division courses. The College has been at the forefront of developing computer-assisted materials for teaching biology. One major effort is known as The BioQUEST Library, an anthology of computer-based materials for biology laboratory instruction.

With initial support from the Annenberg/Corporation for Public Broadcasting Project, BioQUEST has involved biologists, educators, computer scientists, and others in developing 20 software modules for use on Apple Macintosh computers, and eight other modules associated with existing computer software. These modules reflect the underlying philosophy of the BioQUEST Curriculum Consortium: posing questions, pursuing the problems arising from those questions, and persuading others of the value of their solutions. Another important objective, as noted by Dr. John Jungck, Professor and Chairman of the Biology Department and HHMI program director, is to allow students to experience the long-term strategies of scientific research.

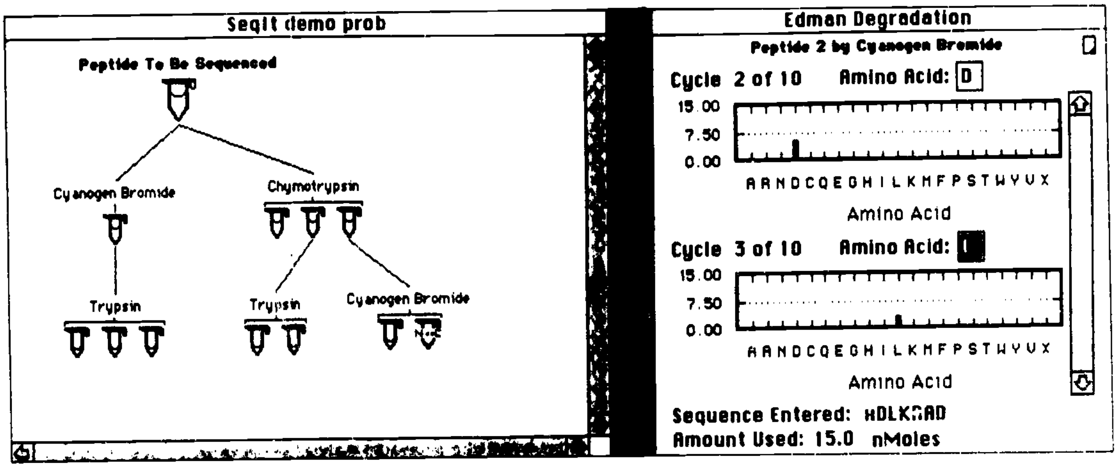
Each of these modules is designed to enable students to practice collaborative, open-ended, in-depth scientific inquiry that supplements laboratory instruction. Among the scientific fields addressed in the modules are genetics, molecular biology, and physiology. BioQUEST modules also allow students to transfer their data, graphics, working hypotheses, and analyses into word-processing, spreadsheet, and scientific graphics software to build scientific journal–style manuscripts that can be reviewed by instructors and other students.

BioQUEST produces The BioQUEST Library, which Dr. Jungck describes as "an electronic academic journal." At the core of the library, which is currently available on CD-ROM in Macintosh format only, are five computer simulations that allow students to gain research experience in various areas of biology. The simulations include "Biota," which simulates species interaction in diverse environments; "Environmental Decision Making," which allows students to create and study model ecosystems; "Genetics Construction Kit," which simulates a classic Mendelian genetics laboratory; "Isolated Heart Laboratories," which allows students to explore the pressure-volume relationships found in the heart; and "SequenceIt!," which simulates the experimental processes used in protein sequencing.

When students run the "SequenceIt!" program, for example, a schematic diagram of a polypeptide of unknown length and sequences appears on the screen. Using a computer mouse, students can then choose from a number of scientific procedures (e.g., acid hydrolysis) built into the program and apply them to the peptide to help determine the amino acid sequence. Each procedure will provide clues as to the physicochemical properties of the protein. Over time, students can use the clues to build a hypothesis, which they will have to defend to colleagues.

With Institute support, science faculty members have developed other computer-based materials for biology instruction. Dr. Jungck, Patti Soderberg, Director of the BioQUEST Curriculum Consortium, and Ben Jones, a computer programmer, have been developing a new software package called INHERIT, designed to help students learn aspects of genetic counseling.

Faculty members are involved in developing materials on real-time data acquisition for human biology, physiology, and neurobiology courses. Professor Marc Roy has written a manual on com-



Sample screens of SequenceIt!, a computer-based series of experiments developed by BioQUEST library authors Dr. Allen Place and Thomas Schmidt, allows students to sequence a polypeptide using simulations of biochemical analyses.

puter interfacing, real-time data acquisition, and analogue-to-digital conversion for other faculty members and students. Professor Ken Yasukawa is developing a series of laboratory and field exercises in animal behavior and ecology for use in high school and college curricula.

New Equipment for New Programs

The Institute's grant is supporting [illegible]ment acquisitions for these [illegible]ities, including a biological image analysis workstation used for such courses as botany, genetics, human biology, and a senior seminar. The workstation will also be used for a cellular and molecular biophysics course. In addition, the grant has supported the development of another computer laboratory consisting of 12 networked Macintosh computers.

The biological image analysis workstation is used by cellular and molecular biophysics students to measure and record the harmonic oscillation of ciliary beating in *Stentor*, a large protozoan; to process graphically pictures of cells whose membranes are in the process of dividing to statistically test whether the pattern is more likely a Voronoi polygon or an L-mosaic spatial distribution; and to study the statistical mechanics of RNA folding.

Developmental biology students use the biological image analysis workstation to measure volume changes in an embryo as it divides from a single fertilized egg to a 32-cell stage; to reconstruct three-dimensional embryos from serial sections and then to make measurements from new "optical" slices; and to change coloring, texture, sharpness, etc., of histological samples in order to better visualize microanatomical structures.

The workstation is used in a large variety of courses to input visual images from compound

Students Gaoussou Diarra and Qat Allikian (left to right) use a computer program to investigate the origins of the genetic code as part of their summer research project in mathematical biology.

and dissecting microscopes, a videocamera, CDs, a flatbed scanner, videotapes, computer disks, and Internet (e.g., Mosaic), and to output them to 35-mm slides, disks, or videotape. The workstation has afforded enormous flexibility in a wide variety of contexts, and the 21-inch screen enables many students to see simultaneously what their colleagues are able to investigate with their own material.

In 1992 EDUCOM, a higher-education communications group, gave BioQUEST software an award for distinguished natural sciences curriculum innovation in biology, and in 1993 the organization honored BioQUEST's Genetic Construction Kit simulation. That same year Project Kaleidoscope chose BioQUEST as one of its "Programs That Work."

Adapting the Technology for Other Settings

BioQUEST materials are widely used across the country. According to Laurie Spier of the Academic Software Development Group at the University of Maryland, which publishes the BioQUEST Library, nearly 250 individuals and 51 colleges and universities throughout the United States and Canada have acquired the rights to use the software. She anticipated a similar number of orders from Europe, based on recent expressions of interest, once the programs became available overseas late in 1994.

Beloit has developed the BioQUEST Curriculum Consortium, an association of some 3,000 life scientists, educators, and computer scientists throughout the country. The College also hosts annual meetings attended by academic scientists from other institutions to learn about and discuss the new technologies. According to consortium director Patti Soderberg, a growing number of K–12 teachers are requesting assistance in developing educational materials at those levels.

Institute funds also support summer workshops at Beloit for precollege life sciences teachers. A major goal of these workshops, according to director Kathleen Greene, is to present a view of science teaching and learning that is open-ended, interdisciplinary, and active: hands on, and minds on. Problem-posing, problem-solving, and peer persuasion are a central part of that approach.

The first summer workshop, in 1992, focused on the use of BioQUEST materials for the high school classroom. John Kempf, a biology teacher at Fort Atkinson High School in Fort Atkinson, Wisconsin, working with the BioQUEST Genetics Construction Kit, developed a Hypercard database illustrating the genetic characteristics of the fruit fly so that students would be better able to visualize them. As Mr. Kempf notes, the workshop challenged him to think about the role of science at the high school level, especially in regard to conducting experiments with students. It encouraged him to construct experiments that are open ended.

However, Mr. Kempf also had some reservations about the program, saying that the totally open-ended approach to instruction left many of the participants feeling overwhelmed and wanting more structure. The evolution of the workshops has reflected some of these concerns.

"One of the things we've learned," says Ms. Greene, "is that we need to keep the practical issues that teachers have in the foreground and the theoretical issues somewhat more in the background. We've tried to ask teachers, What do you see as the greatest issues for you? Then we can present the information in a way that responds to their needs."

In 1994, Beloit presented two such workshops—one for middle school and junior high teachers, the other for junior high and high school teachers—bringing a total of 25 teachers to campus. As the title "Integrating Life Science and Physical Science: Curriculum Development Workshops for Teachers" indicates, the 1994 institutes integrated physical and life science, using the body as the primary object of study.

One of the aspects of the institutes that teachers find most valuable is the chance to exchange ideas and to work with other teachers. Ken De Forest–Davis, a mathematics teacher at Beloit Memorial High School who attended the 1992 workshop that focused on BioQUEST, says the contacts with other teachers provided him with a group of people to whom he could turn for advice and ideas after he returned to his classroom.

Providing Research Opportunities for Students

Institute funds have allowed students admitted to Beloit to become involved in scientific research during the summer before their first year in college. The Young Scholar Research Program brings a small number of entering freshmen (six each in 1992, 1993, and 1994) to campus, where they work with a Beloit College faculty member on a full-time research project, many using BioQUEST materials.

In addition to working one-on-one with a faculty member, the students attend weekly seminars that help them learn and improve research methods and solve problems that come up during the session. They also attend biweekly writing workshops to help them communicate their findings to scientific colleagues.

The students begin by doing a literature review and developing a research proposal, which is continually revised during the course of the research. They document the progress of their research and give two formal reports on the results, one after three weeks, and the other at a formal poster session at the end of the six-week session.

David Gan, a student from Penang, Malaysia, worked with Dr. Jungck on a research project in theoretical genetics. Mr. Gan and Dr. Jungck used a BioQUEST-associated tool called MacClade to study the evolution of macromolecules called amino acyl transfer RNAs that are involved in protein synthesis. Mr. Gan worked up phylogenetic trees for transfer RNA molecules.

Using the BioQUEST program, Mr. Gan would analyze one or two amino acyl tRNAs from each family of amino acids. As Mr. Gan notes, the project was like studying a family tree, trying to show how one amino acid was more like another, trying to show that the mutations between tRNAs weren't random, but part of a pattern. He also used the software to try to trace the steps of the mutation. Mr. Gan originally planned to attend medical school, but he is now a chemistry and biochemistry major and may pursue a Ph.D. in pharmacology.

Program Director
John Richard Jungck, Ph.D.
Professor and Chairman,
Department of Biology
Beloit College
700 College Street
Beloit, WI 53511
(608) 363-2267
(608) 363-2052 (fax)

Institutional Profile

Total enrollment	1,211
Undergraduate enrollment	1,085
Number of faculty members	87
Endowment (millions)	$44
Annual budget (millions)	$26

Educational Technology: Supplementing Laboratory Instruction Harvard University

Harvard University is a private research institution in Cambridge, Massachusetts. In 1992 the Howard Hughes Medical Institute awarded the University $1,100,000 to support (1) development of the upper-division bioscience curriculum to include new project laboratories in developmental biology, genetics, and neuroscience; (2) enhancements in the introductory-level chemistry and physics curricula and creation of a computer laboratory to model macromolecules for a course in organic chemistry; (3) research experiences in university and medical school laboratories for undergraduates, particularly women and underrepresented minority students; and (4) activities to enhance high school biology through laboratory experiences for teachers and students, lectures and demonstrations by faculty members, and development of laboratories for advanced placement biology courses.

The Computer Modeling Laboratory

A computer modeling laboratory has been designed to accompany the University's introductory two-course sequence in organic chemistry. The first-semester course, Principles of Organic Chemistry, is an introduction to the structure of organic molecules, their bonding patterns and reaction mechanisms, the transformation of common functional groups, and the principles of organic synthesis. The second-semester course, Organic Chemistry of Life, deals with the application of organic chemistry to biochemistry, covering such topics as rational drug design and how environmental agents cause cancer. The computer laboratory is designed to enhance the wet laboratory component of the courses.

With HHMI support, Dr. Gregory Verdine, Professor of Chemistry, began to assemble the computer modeling laboratory by purchasing graphics software and four Silicon Graphics Indigo computers. Three more computers were purchased with support from additional sources. With only seven computers, the 300 students who ordinarily take the course could not be accommodated. Consequently, when the laboratory was first offered in the fall of 1993, students were given the opportunity to work in groups on an extra-credit project that used the new laboratory.

Over 40 percent of the students welcomed the chance to work on the extra-credit project. At the beginning of the semester, they were asked to submit a proposal outlining the scope of their project. During the next six to eight weeks, they worked with Dr. Verdine or his teaching assistant—a graduate student specifically assigned to the com-

Dr. Stephen Harrison (left rear), HHMI program director, instructs high school science teachers Marian Levinstein, Robert Siggens, and Catherine Dollard (rear to front) during a workshop on the use of computer graphics to help students grasp principles of biomolecular interactions.

puter laboratory—to refine their proposals.

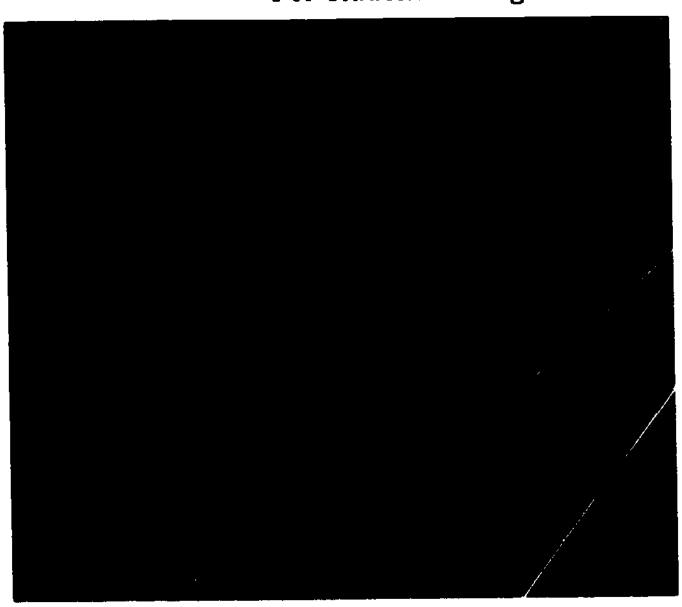
One of the students was John Koski, a senior majoring in neurobiology, who is interested in attending medical school. Working with another student, he used HyperChem software to create a visual image of a common organic reaction called an S_N2 reaction. This reaction, often involving different chemical groups, consists of the substitution of one electron-rich negatively charged group for another. When displacement occurs during the S_N2 reaction, it causes an inversion of the geometric arrangement of the groups. Said Mr. Koski, "A lone atom attacks and causes the whole molecule to invert like an umbrella in the wind." The reaction so lends itself to graphical depiction that Mr. Koski and his partner videotaped the reaction from the computer screen and presented the video in the public poster session at the end of the course.

The value of computer graphics was extolled by Dr. Stephen Harrison, HHMI Investigator, Professor of Biochemistry and Molecular Biology, and program director. He pointed out, "With computer graphics there is no limit to the complexity of the molecule that you can look at. Simple insights can now be extended to enzyme-active sites in a way that is accessible to a large number of people." He added, "The plastic physical models we used to use were prohibitively expensive, very delicate, and impossible to do things with. The computer dramatically extends our ability to teach what is a key concept in modern biology and chemistry—the relationship between 3-D conformation and reactivity."

One of Dr. Verdine's goals is to build the computer laboratory to the point where it can be fully integrated into his organic chemistry courses. A second goal is to realize his long-term objective of combining organic chemistry and biochemistry into a new introductory course. Said Dr. Verdine, "The computers have helped us to flesh out some of the ideas in how we would manage the integration of biochemistry and organic chemistry. An important part of that interface would be the use of computers as a unifying tool."

Expanding Technology

With the new video and computer graphics laboratory, Harvard University is exploring new dimensions in educational technology. The development and production of the video *Inventing the Atom* is intended to expand students' understanding of atomic theory in an introductory course combining chemistry and physics. For students in organic chemistry, complex macromolecular structure can be visualized, twisted, and turned in three dimensions, thanks to an innovative computer modeling laboratory.



Three-dimensional "sliding clamp" model of the DNA polymerase III beta subunit–DNA complex produced by undergraduates Lawrence Brown, Bianca Hovey, Rotonya McCants, Nhi-Ha Trinh, and Kristen Van Amburg with the aid of a Quanta computer graphics program.

The HHMI-supported video—designed to accompany one of the early lectures in Introduction to Chemistry and Physics—reveals the historic roots of our modern understanding of atoms and the kinetic theory of gases. Its underlying purpose is to show how a simple idea in science becomes an accepted fact through use of the scientific method. While the immediate audience for the 30-minute video is the 15 students in a combined chemistry and physics course, the instructor, Dr. David Layzer, Donald H. Menzer Professor of Astrophysics, envisions a broader audience that would include advanced high school physics and chemistry students.

Even though Greek philosophers first postulated the idea of atoms, Aristotle's rejection was sufficient to have their speculations fall out of favor. It was not until the early 1800s that chemist John Dalton espoused the atomic hypothesis, based in part on Newton's *Principia*. The main components of Dalton's theory were correct, but the details were partially incorrect, such as the assertion that all elemental gases were made up of single atoms.

In reality, some gases consist of diatomic molecules like O_2 and N_2. On the strength of Dalton's reputation and his invocation of Newton, experimentalists embraced Dalton's theory, yet struggled for almost 50 years to verify its details, only to be stymied by the lack of empirical support. By mid-century, scientists had all but abandoned the atomic hypothesis. However, in 1870 physicists August Kronig and Rudolph Clausius revived the atomic hypothesis by building on the work of Daniel Bernoulli from over a century earlier. Their kinetic theory of gases, which is widely accepted today, incorporates the atomic hypothesis to explain how gases behave under different conditions of temperature and pressure. "The video demonstrates the scientific method in all of its wide detours. It is a sociological portrait of science," said Dr. Layzer.

Making the video also was not without detours. The original script was considered to be too dry, bordering on an illustrated lecture, according to Dr. Layzer. The first draft was a chronological rendition of events, using still photographs and narration. Both Dr. Layzer and his research assistant felt that the historical development of atomic theory could be illustrated more dynamically through the video medium. An offer from the Harvard Audio/Visual Department enabled them to take advantage of state-of-the-art equipment and a studio. The second script was written, interweaving the historical events, with present-day students in the leading roles. The students interrogate each other about atomic theory.

As a companion to the video, Dr. Layzer and his assistants are developing interactive computer animations to strengthen students' understanding of the kinetic theory of gases. They are writing a computer program using special Macintosh software that visually illustrates Boyle's and Charles's Laws. The computer screen shows two separate gas chambers containing molecules moving at random. The student can manipulate such parameters as temperature, volume, and the number of atoms to assess the impact on pressure.

Program Director

Stephen C. Harrison, Ph.D.
Investigator, Howard Hughes Medical Institute
Professor of Molecular and Cellular Biology
Department of Molecular and Cellular Biology
Harvard University
7 Divinity Avenue
Cambridge, MA 02138
(617) 495-4106
(617) 496-6148 (fax)

Institutional Profile

Total enrollment	18,626
Undergraduate enrollment	6,691
Number of faculty members	5,613
Endowment (billions)	$5.8
Annual budget (billions)	$1.3

Educational Technology: Supplementing Laboratory Instruction University of Puerto Rico Mayaguez Campus

The University of Puerto Rico Mayaguez Campus is a public comprehensive institution. In 1993 the Howard Hughes Medical Institute awarded the University an additional grant of $500,000 to support a program to (1) renovate a laboratory facility for undergraduate instruction in such areas as cell physiology, virology, immunology, and molecular genetics, and acquire equipment for courses in general biology for majors and nonmajors, general biology, and genetics and structural biology; (2) enhance student research experiences to provide opportunities for students to attend scientific meetings; and (3) conduct introductory workshops in molecular biology for local high school biology teachers.

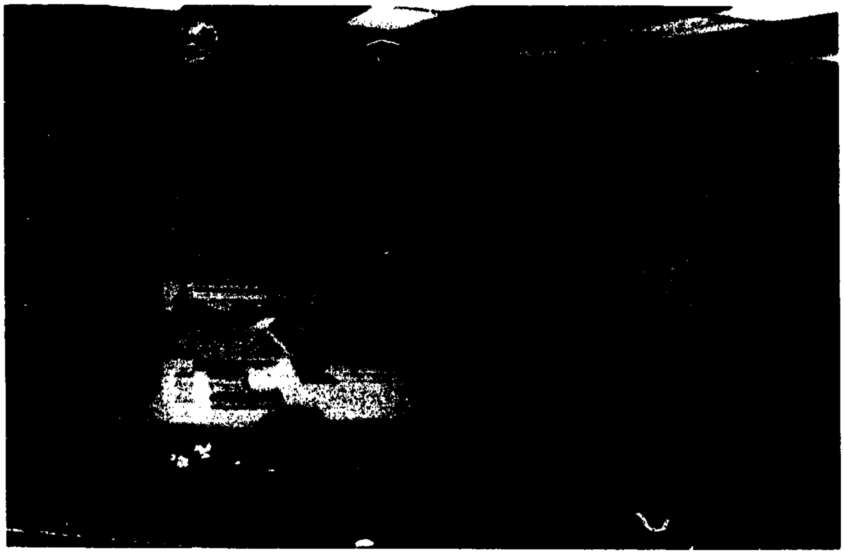
Science on Wheels

Using their 1991 grant from the Institute, members of the science faculty at the University have developed a Science on Wheels project in which a van travels along the western coast of Puerto Rico, visiting rural towns where the schools often lack modern laboratory equipment. The project focuses on Hispanic students in outlying areas of Puerto Rico, but the van has also visited the neighboring Virgin Islands, according to Dr. Juan G. González-Lagoa, Associate Director of the Resource Center for Science and Engineering and HHMI program director on the Mayaguez campus. The purpose of the visits is twofold: to demonstrate basic scientific principles to precollege students and their teachers and parents, and to train precollege teachers to do hands-on laboratory exercises in the classroom with their students. The faculty who travel with the van have found that teachers who receive training are more likely to participate in the van demonstrations.

The Science on Wheels project, part of a larger program for K–12 schools, appeals mainly to students in the 7th–9th grades. The settings are often as informal as an open basketball court.

By allowing the van to travel freely, the faculty can reach many more students than could come to the University campus. Over a year, the van may visit as many as 4,000 students and their teachers; the program is very cost-effective.

"The approach they're taking is very exciting," Dr. González said, referring to the group of science faculty members led by Dr. Juan López Garriga, Professor of Chemistry, who designs and conducts the demonstrations. The group includes Drs. Idelfonso Muñoz, Vivian Torres, and Yolanda Echevarria, as well as an undergraduate student.



Elementary and secondary teachers observe Professors Vivian Torres and Ildefonso Muñoz demonstrate techniques for teaching chemistry.

The van is equipped with computers, balances, and other items to make a small lab. The faculty use simple materials that are readily available and experiments that can be easily repeated. The program receives numerous requests from schools to visit and do demonstrations that are understandable.

Visiting faculty from universities in the continental United States have also participated in the van visits. One was Dr. Henry Bent, who directs a similar van program at the University of Pittsburgh. Another was Dr. Gerald T. Babcock of Michigan State University, who presented a computer-aided demonstration on photosynthesis.

A Visit to a Neighboring Island

During the spring of 1994, the project made its first trip outside Puerto Rico—to the Virgin Islands. To save on costs, the laboratory equipment was crated for transport and repacked in a rental vehicle, once the group from the University arrived. Although the demonstrations in Puerto Rico are usually conducted in Spanish, the bilingual faculty switched to English in the Virgin Islands. Dr. González noted that the project succeeded in the totally different setting because of the factors that were constant—the expertise and enthusiasm of the faculty—who taught the same concepts as they do on their Puerto Rican tours.

"The experiments we do are presented like a classical magic show," said Dr. López. "But we make it clear to the students that this is science, not magic." In one demonstration, Dr. López produces a sold polymer from a liquid mixture. "We call attention to how it's done and explain the importance of polymers in different fields of physical science and biology," he said.

Because the audiences sometimes include more than 500 students and their teachers, the faculty make every attempt to hold the students' attention. They make sure that the presentations keep pace, and they call for volunteers from the audience.

The demonstrations are deliberately kept simple and entertaining to capture the students' imaginations and show them how scientific principles apply to these seemingly magical tricks. In this way, students probably understand the concepts better than if they were taught with sophisticated equipment. During the second year of the van visits, for example, compressed gases, dry ice, liquid nitrogen, acids, and bases were used for demonstrations involving flames, condensation, evaporation, explosions, and colors. A simple kinetic-molecular mode and acid-base chemistry were used to explain the phenomena.

The van also carries a computer that can be hooked up to a television monitor for more sophisticated demonstrations of molecular modeling in biology and chemistry, and parts of a living cell, for example.

Nonetheless, the emphasis is on simplicity and the use of low-cost materials that are available to everyone. Dr. López encourages both teachers and students to purchase materials from local supermarkets to do basic experiments in biology and chemistry. He noted that water in which cabbage has been boiled can be used to test the pH of readily available materials such as lemon juice and ammonia. Although many of the exercises require teacher supervision in the laboratory, some are simple and safe enough for students to try at home.

Dr. Juan López Garriga and Professor Sylvia Márquez de Pirazzi with the Science on Wheels van.

The Van as a Recruitment Tool

The van serves to recruit teachers from outlying areas to attend summer workshops on the Mayaguez campus, where they learn to do the demonstrations they have seen in the van, as well as other experiments they can take back to the classroom. By doing this, Drs. López and González are hoping for a domino effect to stimulate interest in science as they train more teachers and reach more students.

The van visits are also coordinated with efforts to recruit students for the six-week science camp in the summer. As many as 1,000 students come to Mayaguez for classes and laboratories. During the summer the faculty develop new demonstrations for the next van visits.

The University received an additional HHMI grant in 1993 that builds on the initial award by providing support to renovate and equip a laboratory at which workshops on molecular biology are held. These workshops, covering such topics as restriction mapping, bacterial transformation, and gene cloning, provide residential summer training for 10 high school teachers annually.

Program Director

Juan G. González-Lagoa, Ph.D.
Professor, Department of Marine Sciences
Associate Director,
Resource Center for Sciences and Engineering
University of Puerto Rico Mayaguez Campus
Box 5000
Mayaguez, Puerto Rico 00681
(809) 831-1022 or 1025
(809) 832-4680 (fax)

Institutional Profile

Total enrollment	10,498
Undergraduate enrollment	9,913
Number of faculty members	772
Endowment (millions)	\$0.3
Annual budget (millions)	\$95

178

Overview of Assessment Strategies

University of Arizona, 157
University of California–San Diego, 162
Wellesley College, 169

Student Tracking in Research and Prefreshman Programs

Tuskegee University, 174
University of Michigan—Ann Arbor, 179
Williams College, 183

Curricular Reform: How Well Is It Working?

Bates College, 189
Carnegie Mellon University, 195
University of California–Los Angeles, 200

Assessing Outreach Programs

North Carolina State University, 206
University of Chicago, 211
Villanova University, 216

Overview of Assessment Strategies University of Arizona

The University of Arizona is a public research institution in Tucson, Arizona. In 1989 the Howard Hughes Medical Institute awarded the University $1,500,000 to (1) support students through providing paid research experiences; (2) establish a computer learning lab for students and engage the faculty in using computers in teaching; (3) upgrade equipment for biology laboratory courses; and (4) develop and implement programs to reach teachers and students from the 4th grade through high school.

A Busy Place

The Undergraduate Biology Research Program (UBRP) is the centerpiece of the University of Arizona's HHMI-supported activities and attracts a growing number of students and faculty sponsors. The program strives to include as many undergraduates as possible in research and to provide a wide range of projects on which to work. Another way to enhance undergraduate education has been through the establishment of the Biology Learning Center, a computer-based biological resource center that is used by 2,000 students a year.

HHMI funding also supports several outreach programs to stimulate involvement of precollege students and teachers in science. Five programs have been developed: The Marvelous Munching Melanoplus and the Manduca Sexta Project (both for elementary school children), Science Connection, the High School Biology Research Apprentice Program, and the Teacher/Pre-service Teacher Research Experience. Horizons Unlimited and Med Start, two established ongoing programs for high school students, receive supplemental support from the HHMI grant that enables them to include more students. All of the outreach and precollege programs are connected to ongoing biological research at the University of Arizona.

The Undergraduate Biology Research Program

Since the UBRP began in 1988, 441 undergraduates have participated. During the summer of 1994, 130 students worked in biologically related laboratories. The number of faculty sponsors has grown to 204, from 35 different departments. Faculty sponsors provide half of the students' support and all of their research supplies.

A student advisory committee meets weekly to provide guidance to the program's policies and activities. During 1993–1994, this group was instrumental in organizing a lecture series, which included ethics seminars, and several field trips, including a saguaro harvest, a tour of the artificial heart lab, and a visit to

Buenos Aires Wildlife Refuge in southwestern Arizona.

The program emphasizes involvement of students as early as their freshman year. Although this policy has been questioned by colleagues from other universities, a survey of faculty sponsors confirmed a preference for involving underclassmen with little or no experience. These students respond enthusiastically to working in the lab. According to faculty and students, the research experience improved students' grades because coursework became more relevant.

According to Dr. Sam Ward, Professor and Head of the Department of Molecular and Cellular Biology and HHMI program director, "We feel that the undergraduate research program provides an effective model for research universities to utilize their special resources to enhance instruction at the undergraduate level." An article describing UBRP entitled "Improving Undergraduate Biology Education in a Large Research University" was published in the February 1994 issue of *The Molecular Biology of the Cell.*

In January 1994, the University convened the fifth annual UBRP conference. Current UBRP students, their families, program alumni, outreach program participants, faculty sponsors, and university administrators attended. University students and outreach participants presented their experimental results in poster form. Jennifer Gilmartin, a junior at the University, reported her research on the effect of alcohol on sympathetic neurons, using an *in vitro* model of neuronal development.

Ms. Gilmartin works with Dr. Mary Johnson, Professor of Pediatrics. They discovered that alcohol inhibits dendritic development while enhancing axonal elongation. Recent studies have shown that Schwann cell numbers are decreased by alcohol, possibly by inhibition of mitosis. The intent of this work was to better understand fetal alcohol syndrome, a prenatal insult that harms a large number of infants each year and is a leading cause of mental retardation. Continuation of this work could help to determine whether a "safe" amount of alcohol exists to which a fetus can be exposed without damage to the nervous system.

Shane Uswandi and Naomi Rance worked in a laboratory at the Department of Pathology in the School of Medicine. They used samples of brain tissue obtained from postmenopausal women at autopsy to determine whether increased expression of the gene for luteinizing hormone–releasing hormone preceded increased secretion of luteinizing and follicle-stimulating hormones.

The UBRP conference proceedings included abstracts of the posters presented. Listed in the proceedings were the names

During the 1994 undergraduate research symposium, Shane Uswandi, an undergraduate, explains how increased expression of a gene in the hypothalamus region of the brain in postmenopausal women may cause the anterior pituitary gland to release hormones.

of participants in the outreach programs and the current activities of program alumni. Including students and faculty from the outreach programs in the UBRP Conference has been an effective means of informing them about the opportunities available through the UBRP Office. It also enables students to meet biology faculty and to maintain contact with program organizers and fellow participants.

Keeping in Touch

One of the most difficult, but most important tasks in assessing the program's effectiveness is tracking past participants. The voluntary effort by the students that is required to keep in contact is facilitated if participants appreciate the program and develop an identification with it. This goal is accomplished through program activities and a monthly newsletter, which keeps students and alumni in communication with one another and with the faculty. E-mail accounts are being obtained for all students, enabling staff to reach a growing number of participants and alumni via the Internet.

It is essential for communication and for reporting purposes to have a reliable database. Jerome Jahnke, senior applications systems analyst, has developed a database that includes the name, local and permanent addresses, ethnicity, birthdate, sex, career goals, source of funding, number of scientific papers/presentations made, and program evaluations by participants and faculty. The evaluations can offer insight into the design of an effective undergraduate research program. Collectively, this information has been important in tracking participants and in evaluating long-term program outcomes.

Carol Bender, UBRP director, noted, "The HHMI grant has enabled us to develop a spirit of community among participants in all of our programs. This sense of community is vital to achieving our program goals."

Promising Results

To date, 269 of the 441 undergraduates who participated in UBRP have received bachelor's degrees. Eighty-five students (31 percent) have entered medical school, and 71 (26 percent) have entered graduate school.

Students' accomplishments indicate that the program is achieving its goal of exciting students about biological research. More than 100 UBRP students have published their research results, and the work of nearly 150 students has been presented at scientific meetings. Moreover, since 1992 UBRP students have traveled to other countries to be a part of the international scientific community. To date, 23 UBRP students have worked abroad on projects related to their work at the University.

In 1994 UBRP students were working in Germany, Sweden, France, the Czech Republic, Brazil, Canada, and Japan. Students and faculty sponsors in the host countries are uniformly enthusiastic about the "International UBRP." In the words of Dr. Francoise Pecker, Research Director at the Henri Mondor Hospital in Paris, "I am writing to express how glad I am that Brian Van Tine had the opportunity to come to our lab....Brian accomplished a lot of work and got interesting results...this has given us the unique opportunity to start a collaboration, which is promising, with the laboratory of Professor Victory Hruby at the University of Arizona."

UBRP student Paul Klekotka wrote of his experience at the Karolinska Institutet in Stockholm, Sweden, "I wanted to learn how scientific research is conducted in a foreign country....this summer has been one of the best experiences of my life...I learned the importance of linking basic research to clinical aspects and also about the need for basic research. My summer experience has caused me to decide to pursue an M.D./Ph.D. degree."

UBRP students have been successful, too, in securing National Education Security Act (NESA) awards to study abroad in Botswana, China, Madagascar, and Senegal.

Four UBRP alumni were awarded NSF predoctoral fellowships during the past year and three received honorable mention. Diane Thomson, a UBRP student, was awarded one of 10 Churchill Fellowships given nationally. Ms. Thomson will study environmental policy in the developing world at Cambridge University in England. From 1993 to 1994, five UBRP students received the Goldwater Scholarship in Math and Science.

These and the other honors UBRP students have received reflect the depth of commitment students and faculty make to scientific research.

The Biology Learning Center

The Biology Learning Center (BLC), a computer laboratory dedicated to exploration of biological concepts, was established using funds from the HHMI grant. Students can use programs like "Macmolecule," which was developed at the University, to view macromolecules as three-dimensional color images. Students can manipulate the molecular models to gain a greater appreciation for the complexity of biological structure and the relation between structure and function.

Other computer-generated programs such as "DNA Inspector" and "DNA Strider" involve drawing tools and color animations that enable students to manipulate DNA sequences. BioNet, an electronic bulletin board, was developed for use by undergraduates. Students use BioNet to communicate with each other and with their professors. With funds from an NIH Bridges to the Future grant, the University has established remote BLCs at Navajo and Pima Community Colleges.

Program Director

Samuel Ward, Ph.D.
Professor and Head of Molecular and Cellular Biology
Professor, Ecology and Evolutionary Biology
LSS Building, Room 444
University of Arizona
Tucson, AZ 85721
(520) 621-7563
(520) 621-3709 (fax)

Institutional Profile

Total enrollment	35,279
Undergraduate enrollment	26,558
Number of faculty members	1,603
Endowment (millions)	$60
Annual budget (millions)	$735

Overview of Assessment Strategies
University of California–San Diego

The University of California-San Diego is a public research institution. In 1989 the Howard Hughes Medical Institute awarded the University $1,200,000 to (1) enable upper-division undergraduate students in the biological and physical sciences to undertake research with faculty members or industrial scientists and develop their findings into honors theses; (2) provide undergraduates, including black and Hispanic students, with laboratory assistantships, a self-paced program of learning in biology using interactive video technology, and tutorial workshops in biology and related disciplines; and (3) create a summer and academic year program of tutoring, laboratory course work, and research for students selected from San Diego high schools.

An Early Start

Does it work? is sometimes only an afterthought to those who administer science education programs. At the University of California–San Diego, assessment has been part of the Institute-funded program from the start, and that is one reason why the program can answer this important question.

"Part of our original proposal was a plan to do a thorough evaluation," said Gabriele Wienhausen, Ph.D., lecturer and academic coordinator for the Biology Department and co-director of the HHMI program. "We could start from day one collecting data."

The HHMI program at UCSD has three components. A lower-division program provides faculty mentoring, laboratory apprenticeships, a tutorial workshop, research seminars, and academic and career advising to undergraduates. An upper-division section includes summer and senior-year research opportunities. An outreach effort to three local high schools offers science camps in the summer and support for science fair projects during the academic year.

In setting up their program, UCSD faculty developed a multi-layered approach to evaluation and brought in an outside expert to do a comprehensive assessment after the third year, factors they believed would be critical to a successful evaluation of the program.

Plan to Evaluate

Because of funding limits or perhaps through lack of concern, planning for assessment is often postponed until it is too late to do a thorough job. Therefore evaluation must be planned and budgeted from the beginning.

"If you don't have a plan in place, you end up missing important data," explained Dr. Barbara Sawrey, lecturer and academic coordinator for the Chemistry

Department, and co-director of the HHMI program. "It's very difficult to get data about people after you've started."

Planners should consult an evaluation expert when setting up their program, Dr. Sawrey continued. Ideally, that would be the same person who later does the formal assessment. The HHMI program consulted one expert to plan the evaluation and brought in Dr. Betsy Strick, an anthropologist with expertise in evaluating education programs, to conduct the assessment. When the university wrote a second proposal to the Institute, Dr. Strick helped plan the evaluation and was selected to do the assessment as well.

Dr. Strick advocates a multilayered approach to evaluation. "When you look at a program through just one kind of data, you can be misled," she said. If grade point averages were the only type of data used in evaluating the lower-division program, the results would not reveal the program's success in keeping marginal students in science, Dr. Strick said. These students were succeeding in science but were lowering the average GPA for students in the program relative to a comparison group whose correspondingly marginal students left and thus did not detract from its GPA average.

An evaluation is often more valid when there are different types of data to examine. Current grades, previous grades from transcripts, retention rates, and SAT scores where appropriate are standard, useful quantitative data to collect for program evaluation. In addition, interviews or some other type of qualitative data from participants, especially the students, should be included.

So that the data are comprehensive, the HHMI program uses surveys and questionnaires to collect responses from students and faculty involved in program activities on the college level and, at the high school level, from students, science teachers, and guidance counselors.

"If there was a seminar course, we would get the feedback at the end of the seminar. If there was a special one-day workshop, we always had an evaluation form ready for the students to fill out," Dr. Sawrey said. The incoming freshmen were even asked what could be done to improve their two-hour orientation session.

To keep students from becoming resentful about filling out questionnaires, the program strives to offer something in return. Sometimes it is giving students more voice in planning activities, such as get-togethers with faculty. Frequently it involves immediate notification when their suggestions lead to changes—even minor ones—in the program.

Qualitative data can also be generated by having students keep an informal diary, perhaps on a monthly basis, Dr. Strick said. They can be asked to write whatever they think and to address specific questions on aspirations, feelings about the program, or how to solve a laboratory problem. These periodic entries, she said, provide a sense of how student thinking is developing.

The directors pointed out that serendipitous data, too, can be useful. Insight on the progress and direction of the program is offered by a faculty advisory committee. The activities most valued by students are revealed in the level of competition for certain program slots. The breadth of the program's popularity was discovered when answers to a question on the application showed that a strong informal network was feeding local students into the program.

In addition, a system for tracking students after graduation is needed to gather data about the long-term effects of a science education program. Once a year, the program sends a questionnaire to students or their parents, aiming to follow the students through their graduate education into first jobs. Although it is not 100 percent effective, the tracking system has already proved useful in locating former participants to interview for program assessment.

Comparison Group

When planning an evaluation, it is helpful to set up a comparison group. The first choice would be a control group, but a meaningful one is difficult to achieve. The program attempted to establish such a group with students who were not accepted for the lower-division program. Because the program actively recruited underrepresented minorities, the control group ended up with a much different ethnic composition. Comparison between the two groups was further limited by nonrandom departures, with students leaving the control group more frequently than the program.

When a control group is not possible, the general student population provides a good comparison. Dr. Strick was able to locate campuswide data on student grades and retention rates so that she had a general sense of how students normally do at the University.

When a cohort comparison is not possible, a time comparison can work. For that, transcripts are needed to see how students performed before they entered the program. Undergraduates were asked to furnish high school transcripts when they applied to the lower-division program.

For the outreach effort, however, program administrators initially had trouble getting transcripts for students in the three local high schools. If a student is under 18, both student and parents must give permission to access the school records. After obtaining permission, the administrators must contact the schools again to access the records.

Program administrators created a release form to secure permission for access to student records, which is now used routinely when high school students apply to the program. Actually getting those records from school officials, however, remained a problem until the program staff developed a relationship of trust with the schools. A key to building that relationship was hiring able program staff who were diplomatic, open-minded, and approachable.

External Evaluation

To establish the credibility of the program and to protect against bias, an external evaluation is essential. The evaluator should come from outside the departments involved with the program and preferably should have professional experience in assessing education programs and expertise in the evaluation techniques used in the social sciences.

"To look at these issues and to be knowledgeable about using methods that we as hard-core scientists don't know of is very important," Dr. Wienhausen said. "I don't think we have the knowledge to do these kinds of evaluations, because they are not the methods that the hard-core sciences would use."

Dr. Strick had no prior experience with the program, but she had evaluated other education projects. She began by interviewing the staff about the goals and mechanics of the program, then analyzed the collected data and gathered other information from people associated with the program.

Her extensive interviews—with students, parents, teachers, faculty, and program alumni—uncovered particularly useful information that had not appeared on surveys or questionnaires. The interviews revealed how well-respected the high school outreach effort was, not just by science teachers, but by principals, guidance counselors, and even students not in the program who nevertheless felt it was something worth competing for.

The interviews also turned up "unanticipated consequences," beneficial effects that were not explicit goals of the program. Dr. Strick learned that some upper-division students involved with the program's research effort had met foreign scientists and had maintained contact with them in their home countries. She also found that the research experience had persuaded a couple of students aiming for an M.D. degree to seek an M.D./Ph.D.

Dr. Strick conducted a single assessment after the third year of the five-year program. The timing was early enough to locate program alumni easily. But a later evaluation, she said, would have provided more information about their success in graduate school and the evolution of their career plans. Having two external evaluations, a smaller one early and a larger one later, would resolve this dilemma. The earlier evaluation would also test the evaluation mechanism in time to make changes before the final assessment.

Multiple external evaluations, however, are expensive. The program's administrators emphasized the need to find an appropriate balance between the resources devoted to program services and those earmarked for evaluation.

One solution is to do periodic internal evaluations, bringing in an external evaluator once or twice over the course of the program. Another solution is to use an incremental external evaluation. In this case, an outside evaluator would help plan the evaluation and each year thereafter conduct an increasingly broader assessment.

The first year would be devoted mainly to collecting data, which the evaluator would examine to make sure the system was on track. Most of the evaluation would proceed in subsequent years, so the need for the evaluator would grow over the program.

Benefits of Evaluation

Program evaluations cost time as well as money, but the benefits have been worth the expense, the program directors say. Besides demonstrating program effectiveness and eliminating questions of bias, evaluation has identified program strengths and weaknesses and has provided authority to act on those discoveries.

Activity assessment questionnaires provide insight about what works best for students and what therefore might be repeated or expanded. A student who had participated in one of the program's research seminars on genetic engineering wrote that "the instructor made the class lively and very interesting all the time. Even though I had little background in biochemistry, I've gotten hooked on the subject." Such evaluation information can be persuasive when asking faculty to offer a course again or to teach a new one.

Similar questionnaires reveal how participating faculty feel about the program and its students. One professor wrote that a student in the laboratory apprenticeship program "is interested and enthusiastic about the research. We continue to give him more responsibility with no worries. There is a very good chance we will fund him full time this summer."

One student, Amara Siva, did research on the *p53* gene, which is the most frequent target of mutations in human cancers and is involved in the development of both sporadic and some hereditary breast tumors. Her goal was to determine the location and types of mutations found in metastatic breast tumors and to characterize these mutations. A comparison of these mutations with those found from primary breast cancer was done to find a possible correlation of the progression of the disease with frequency and type of mutations in the *p53* gene.

Ms. Silva used the polymerase chain reaction (PCR) to copy over and over again a selected portion of the genome, resulting in extensive amplification. Alterations (mutations) in the copied sequence shifted the migration of the PCR products through a polyacrylamide gel. Gel analyses showed *p53* point mutations in four regions coding for *p53*. Detailed nucleotide sequencing experiments are now under way.

The continual evaluations—"reality checks"—have led to a range of program corrections, from minor tweaks in scheduling activities to major changes in program and personnel.

Student response has often indicated when the timing for a particular activity was off: a certain event might be more effective if set early in the quarter rather than during the week before finals. Student evaluations helped convince the directors to replace a high school outreach coordinator with someone who provided a stronger role model and who had better rapport with students.

High school student Darryl Sykes and his parents (right to left) attend an orientation session of the University of California–San Diego's Summer Science Camp.

Student and faculty questionnaires also suggested a need to alter the faculty mentor program. Initially, the program matched all its incoming freshmen with a faculty mentor. Faculty members were unsure, however, about what to do with freshmen who were still searching for academic direction and had not yet declared a major. They wanted students a little more focused. As a result, students are now assigned to a faculty mentor at their own request, and several program activities have been designed to help students develop and clarify their interests in science.

The Ethics of Evaluation

The evaluation plan initially called for a control group composed of students who had applied to the program but were not accepted. When it was decided to bring as many underrepresented minorities as possible into the program, the control group was left with little representation from these minorities, a situation that greatly reduced its usefulness for evaluation. It was decided, however, that providing services to these students is more important than the evaluation.

The two goals of providing services to students and conducting a rigorous evaluation need not present an ethical dilemma. With a range of techniques available, programs need not sacrifice service to conform to any one evaluation method.

There is no one right way to assess a science education program, Dr. Strick concluded. Evaluations can and should be customized to fit the structures and goals of a particular program. But be sure to plan the evaluation from the start, use a multilayered approach, and bring in an outside evaluator.

Program Director

Gabriele Wienhausen, Ph.D.
Tenured Lecturer and
Academic Coordinator
Department of Biology
University of California–San Diego
La Jolla, CA 92093-0355
(619) 534-3018
(619) 534-1835 (fax)

Institutional Profile

Total enrollment	16,678
Undergraduate enrollment	14,360
Number of faculty members	936
Endowment (millions)	\$38*
Annual budget (billions)	\$1

*campus

Wellesley College is a private liberal arts institution in Wellesley, Massachusetts. In 1993 the Howard Hughes Medical Institute awarded the College $850,000 in support of programs to attract and retain women in the sciences, to include the following components: (1) summer research opportunities, in collaboration with a faculty mentor, for women and minority students underrepresented in the sciences; (2) equipment acquisitions to strengthen classroom and laboratory instruction in biology and chemistry at the introductory level; and (3) programs to enhance the quality of precollege science education.

Women in Science

As a women's college, Wellesley is an ideal place to study how women become interested in scientific careers. Based on longstanding concerns about the underrepresentation of women in the sciences, Wellesley launched a research project in 1991 entitled "Pathways for Women in the Sciences." This extensive project, supported by the Alfred P. Sloan Foundation, is an exploration of the academic and personal factors motivating women to pursue scientific careers. The college has already translated some of the Pathways findings into concrete steps designed to retain students in the sciences.

Chandra Miller, a 1994 African American graduate from Wellesley, epitomizes Pathway's findings. As a chemistry major, she performed HHMI-supported independent research in the laboratory of Dr. Jean Stanley, Associate Professor of Chemistry, where she undertook a conformational analysis of delta-lactone rings, organic structures found in many natural products with therapeutic value. Mentors and hands-on research played a prominent role in cultivating her interest in chemistry. "After I took chemistry in my junior year of high school, I came to Wellesley wanting to major in it....Not only have professors like Dr. Stanley encouraged me, but I was fortunate enough to have a graduate student take me under his wing one summer at the University of Rochester and teach me everything about laboratory chemistry. This increased my confidence to work independently in the lab."

Ms. Miller entered a chemistry doctoral program at the University of Texas at Austin in September 1994 with the expectation of teaching at the college level. She would like to promote science education at the high school le el "in return for the encouragement" she received during those years.

Ms. Miller's experience at Wellesley began the summer before her freshman year. She was a participant in the Summer Enrichment Program, which is

Yvonne Wilson, a junior, observes the growth of mouse adrenal cortex cells in cell culture while investigating the effects of the adrenocorticotropic hormone on the activity of protein phosphatases.

partially supported by the HHMI grant. This is a four-week residential program for about 30 students who have been admitted to Wellesley, a majority of whom are underrepresented minorities.

The program enhances academic preparedness and self-confidence for college entry. Students are offered noncredit courses in science, writing, and study skills. During this program, Ms. Miller became acquainted with Dr. Stanley, who taught the science course and later encouraged Ms. Miller to join her laboratory. "I am thrilled at Chandra's progress, and I know that the summer enrichment program jump-started her academically," said Dr. Stanley.

Longitudinal Tracking

The hallmark of the Pathways project is a longitudinal study of over 500 students entering the class of 1995. Longitudinal research has the advantage of closely tracking how career choices are shaped by events during the college years. During the first phase of the project, a detailed questionnaire was given to students at three pivotal times—college entry, completion of introductory science and math courses during the freshman year, and midway through the sophomore year, when students are required to declare a major. Also studied in the first phase were Wellesley science majors who graduated in 1983–1991. During the second phase, which will be in progress for the next two years, more than 2,500 Wellesley alumnae who graduated between 1968–1982, 40 percent of whom were science majors, will be surveyed, and the entire class of 1995 will be followed through graduation and six months beyond.

Among the most important findings from the first phase is that many women begin college with an interest in science, but fewer actually become science majors. The attrition rate is about 20 percent. In addition, few women who enter college with interests outside of science become science majors. According to Dr. Nancy Kolodny, Dean of the College and Professor of Chemistry, "More women are starting in the sciences, but we continue to lose them...It is so important to look more closely at factors that attract women to science and keep them there."

The educational environment can make a difference in sustaining students' interest in science. Pathways researchers learned that the 64 percent of the 1983–1991 graduates who remained in science were more likely to have had mentors, role models, and hands-on research at the college.

Mentoring for Minority Students

Pathways has helped to reinforce or stimulate the need for mentoring programs, particularly for minority students. One of its first longitudinal analyses evaluated the students who took advantage of the summer enrichment program. It found that many of the participants began with positive attitudes about the sciences but experienced academic difficulties in the college math and science courses, where they performed at a lower level than in their nonscience courses. Very few of the summer enrichment program students went on to major in the sciences.

This finding prompted Dr. Mary Allen, Professor of Biological Sciences and HHMI program director, to work with three of her colleagues on a new program to ease the transition of underrepresented minorities to the rigors of academic life at Wellesley. First Year Minority Mentorships in Biology and Chemistry began in the fall of 1994. Ten entering minority students are matched with Wellesley faculty mentors and are given a HHMI-supported stipend for conducting research during their freshman year. In addition, the students participate in all laboratory-sponsored events and attend seminars and special workshops designed to introduce cutting-edge scientific concepts and promote study skills.

Smaller Classes

Many entering Wellesley students are now also benefiting from smaller classes in several introductory biology and chemistry courses. The need to replace large lecture classes with smaller classes has long been recognized at Wellesley. Almost 20 years ago, the Chemistry Department decreased the

Christine Birchwood (foreground), a junior, prepares a dot-blot to detect the presence of a storage protein in cyanobacteria, and Nicole Jardin, a senior, observes.

number of students in introductory lecture sections. The fact that large classes discourage interest in science was later confirmed by the Pathways project.

With impetus from Pathways, the Biology Department has followed the example set by Chemistry. Starting in 1993, the two main introductory classes, Organismal Biology and Cell Biology, have been reduced from about 200 to 36 students per section. The need for more educational technology to accommodate the increased number of sections was immediately apparent. The HHMI grant enabled faculty to purchase additional equipment such as slide projectors, video equipment, and computer hardware and software. Slides used in some lectures are being scanned into a computer library that is accessible to students through a campuswide computer network. "Because of the new system, students have 'take-home' lectures," said Dr. Allen, who is one of the faculty teaching Cell Biology.

Wellesley uses many vehicles to track student careers. For example, Wellesley faculty and administrators routinely monitor the progress of the 50 percent of graduating science majors who received support as undergraduate research students under Wellesley's earlier HHMI grant. Of the approximately 200 students who received support from 1989–1993, 28 percent have gone on to medical school, 31 percent have entered graduate school in the sciences, and 19 percent have secured positions in science. A high proportion of HHMI-supported students remained in the sciences after graduation, emphasizing the role of hands-on research. Comparisons of the postgraduate career paths of HHMI-supported and nonsupported students are planned.

Dr. Kolodny remarked, "When we make changes, we at Wellesley are now more than ever aware that we should evaluate what we do."

Program Director

Mary Mennes Allen, Ph.D.

Jean Glasscock Professor of Biological Sciences and Director of Biological Chemistry

Department of Biological Sciences

Wellesley, MA 02181

(617) 283-3068

(617) 283-3642 (fax)

MALLEN@LUCY.WELLESLEY.EDU (Internet)

Institutional Profile

Total enrollment	2,245
Undergraduate enrollment	2,245
Number of faculty members	224
Endowment (millions)	$494
Annual budget (millions)	$97

Student Tracking in Research and Prefreshman Programs
Tuskegee University

Tuskegee University is a private historically black institution in Tuskegee, Alabama. In 1993 the Howard Hughes Medical Institute awarded the University $500,000 in support of (1) renovation of biology and chemistry teaching laboratories and creation of a learning center emphasizi g computer-based instruction in biology and chemistry, and (2) expansion of a program that provides students with prefreshman laboratory and classroom training in the sciences, ongoing courses and seminars to strengthen research skills, and research experiences at university, government, and other off-campus laboratories.

An Early Nurturing Program

Tuskegee University received its first grant from the Institute in 1988, to support the Educational Nurturing of Highly Academic National Candidates for Excellence in Science Program. According to Dr. Ollie C. Williamson, Dean of the College of Arts and Sciences and the first HHMI program director, "The goal of the program is to strengthen the national quality of undergraduate education and research in biology...." In particular, he added, the program has aimed at "increasing the number of [graduates] who go on to research, to teaching careers in medicine, health sciences, and the biological and related disciplines—and increasing the number of minority students who choose these fields." To assess these efforts, Tuskegee is tracking the first groups of participants. In 1993 the University received a second grant from HHMI, which continues the nurturing effort.

From 1989 to 1992, the program has attracted about 20 students to the Tuskegee campus each summer for an eight-week session. The heart of the program is an interdisciplinary course in molecular biology, biochemistry, and genetic engineering that features lectures and demonstrations by scientists from other universities, industry, and government agencies. Students also participate in hands-on laboratory sessions. In addition to the science course, they enroll in honors courses in English and mathematics and are actively involved in a general purpose computer course.

During the summer of 1992, groups of four students conducted an experiment using Wisconsin Fast Plants. This experiment was developed by Dr. Paul Williams, a plant pathologist at the University of Wisconsin–Madison. The accelerated cycling of the *Brassica rapa* (rape) plant is demonstrated in approximately 4–5 weeks, whereas the normal life cycle would be several months. Germination, fertilization and nutrition, pollination (using simulated bees), and fruiting occur rapidly, allowing the experiment to be completed during the normal period of a class project.

Although the applicant pool for the summer program reflected the nationwide range of high school students attracted to Tuskegee, half of the 77 participants were drawn from Alabama and neighboring states. Students are chosen on the basis of their high scholastic record, a grade point average of 3.0 or higher, and combined SAT scores of 1000 or better.

During 1989–1992, the program was targeted to precollege students who planned to continue at Tuskegee as undergraduates. Some, however, changed their minds and attended other colleges and universities, according to Dr. J. H. M. Henderson, Professor of Biology and Chairman of the Natural Sciences Division and current HHMI program director. Many understandably chose those that offered the best scholarships or other incentives. Overall, nearly half the participants continued at Tuskegee.

Tracking Prefreshmen

Dr. Henderson and his colleagues "have attempted to find out what the students have done." He pointed out that the mechanism for tracking is rather labor intensive. The first contact is made by mail, but in almost all cases the students must be followed up by telephone, mainly in the evening, since many are not at home during normal working hours. The students who keep in touch with each other help with referrals. This method, while laborious, allows for almost complete coverage, and the results are quite satisfying.

Most of the students who participated in the program have done very well. In fact the majority of those who continued at Tuskegee have had excellent research experiences in the summer, and those who have graduated from Tuskegee have usually received honors or high honors.

One student spent the summer of 1990 at the University of Michigan in the laboratory of Professor John Kuwada of the Department of Neurobiology. The laboratory was concerned with measuring the growth of axon cones and dendrite development as influenced by several antibodies as markers. To demonstrate this, zebra fish were used as experimental animals to determine whether floor plate cells influence the direction of axonal growth during embryonic stages. Mutant fish that lacked floor plate cells died because of axonal malfunction.

The retention rate in the sciences has varied considerably from one year to the next, according to Dr. Henderson. For instance, of the 19 students who participated in the program during the summer of 1989, 12 continued at Tuskegee, most of them majoring either in biology or chemistry. Of the 18 students in the 1990 summer group, only

6 remained at Tuskegee, but 3 did very well as biology majors.

Ten of the 20 students in the 1991 summer program stayed at Tuskegee as biology majors and did well. Other members of that summer group attended schools such as Stanford, Spelman, Xavier, Clemson, Yale, and the University of Alabama. In 1992, 12 of the 20 summer participants continued at Tuskegee, with all but one majoring in biology or chemistry and maintaining a high grade point average. Overall, most participants in the first four years of the summer program have thrived in college, and the great majority have pursued biology or other science curricula, including biochemistry, chemistry, and chemical engineering.

In the class of 1989, of which over half remained at Tuskegee University, two of the students graduated in 1993. One is in his second year of medical school. A 1994 graduate anticipates going to graduate school in 1995 after a year in clinical research. Three have applied to medical school and are awaiting acceptance. Two graduated in 1994 in chemical engineering and are awaiting graduate school in the fall. Two are currently in research positions, one at Oak Ridge, the other at the Life Sciences Division of the Los Alamos National Laboratory. Another graduated with high honors in accounting.

A Shining Example

Dr. Henderson points to one of the program's students, Stephen Nurse-Findlay, with special pride. "Steve, who is a fantastic student, is a shining example of how the program works," Dr. Henderson said. Not only has Mr. Nurse-Findlay done very well in course work and extracurricular activities on the Tuskegee campus, he has also conducted research over several summers at several institutions. Mr. Nurse-Findlay's summer research began in 1991 with Dr. G. R. Hageman of the Department of Physiology and Biophysics at the University of Alabama at Birmingham (UAB). His investigations involved basic clinical procedures and the use of various equipment such as the multichannel polygraph and the 286 computer. He learned such techniques as arterial and venous catheterization, bilateral thoracotomy, and placement of electrodes and force gauges onto atria and ventricles of the heart.

His second summer was spent at the Roswell Park Memorial Institute Center for Photodynamic Therapy, where he worked on characterizing the effect of photodynamic therapy on human pancreatic cells *in vitro*. This *in vitro* assay involved basic cell culture techniques using rather complicated laser alignment, radioactive labeling, and counting techniques. Mr. Nurse-Findlay completed seven

WALTER SCOTT

Participants in Tuskegee University's 1992 summer research program came from 10 states. The class included (front row, left to right) Helishia McLauchin, North Carolina; Terrance Smith, Georgia; Kimbley Thomas, Georgia; Tiffany Bridgeman, Mississippi; Dr. J. H. M. Henderson, program director; Nicole Bell, Mississippi; Matokie Willis, Alabama; Solomon Yilma, California; Dalphine Wilson, Alabama; and Tillery Wilhite, Alabama. Standing behind them are Loleta Harris, Tennessee; Wendy Cooke, South Carolina; Emmitt Jolly, Alabama; Yvonne Harris, Alabama; Wesley O'Neil, Florida; Leslie Gibson, North Carolina; Latoya Sawyer, Georgia; Shelby Alexander, Tennessee; Shawn Hockaday, Alabama; and Kimberly Law, Louisiana. Not pictured is Crystal Gilbert, Michigan.

experiments, six of which were fully evaluated and showed excellent reproducibility and corresponded with initial findings in the laboratory. For his oral presentation of the work, he received Roswell Park's Sidney Farber, M.D., Award for Outstanding Excellence.

Mr. Nurse-Findlay spent the summer of 1993 at the New York University (NYU) Medical Center Sackler Institute of Graduate Biomedical Sciences. He was assigned to the laboratory of Dr. Elizabeth Neucomb of the Department of Pathology to work on a project concerning the characterization of *p53* gene expression in human cell lines. This research is described in a manuscript entitled "Characterization of *p53* Gene Expression in Human Cancer Cell Lines" by Stephen Nurse-Findlay, Anju Thomas, and Elizabeth Neucomb.

In the summer of 1994 Mr. Nurse-Findlay worked in the laboratory of Dr. Joan Goverman at the University of Washington Center for Molecular Biotechnology. Dr. Goverman's laboratory focuses on two areas: first, how T cells mature and acquire immunological tolerance to self-directed antigens; and second, how T cells specific for myelin basic protein, a predominant protein on the myelin sheath of the central and peripheral nervous systems, produce experimental allergic encephalomyelitis.

Other program participants have done research at various institutions, including universities, national laboratory facilities, and private sector laboratories. For example, those who enrolled at Tuskegee have spent summers at Case Western Reserve University, Los Alamos National Laboratory, the University of

200

Michigan, the University of Washington, and Ciba Geigy Corporation. Moreover, many of the summer participants have done research during subsequent summers with faculty members at Tuskegee.

Emmitt Jolly of the class of 1992 worked in the lab of Dr. Jerrie Thompson in the Department of Biochemistry and Medical Genetics, UAB. His research was on Batten's disease, a neurodegenerative disease that results in lack of muscular control, especially in children. A key compound involved in the disease is sialic acid. The question is what role it plays in the lysosomal degradation of glycosaminoglycans. The disease remains unabated, but results show that levels of sialic acid may play a role in its alleviation.

In the summer of 1994, Mr. Jolly did research at the University of California San Francisco Medical School in molecular biology involving phosphorylation of a transcription factor, PHO4, by a cell division kinase complex, using mutants of *E. coli*.

Solomon Yilma worked in the clinical virology lab of Dr. Subhendra Chatterjee at UAB. His research was involved with the effect of mouse interferon on the replication of herpes simplex virus type 1 in mouse-fibroblast cells. The objective was to eradiate the virus with interferon. The experiments resulted in the blocking or partial blocking of the inhibitory effect of mouse interferon by preventing the activation of interferon-induced genes.

At NYU Medical School, Mr. Yilma is studying how ribosomal RNA transcription starts in the yeast *Schizosaccharomyces pombe*. Mr. Yilma's research, under the direction of Dr. Louise Pape, is entitled "Transcriptional Analysis of *S. pombe* Ribosomal Promoter Region."

Kimberly D. Law, who participated in the prefreshman program in 1992, attends Prairie View A&M University in Texas. She is also doing research in the Summer Undergraduate Minority Research Program at NYU under the direction of Dr. Noaka Tanese. The title of her project is "Mechanism of Transcriptional Activation of Glutamine-Rich Activators CREB and Sp1." Her research involves the qualitative interaction of transcriptional activators and a human multiprotein complex.

Program Director

J. H. M. Henderson, Ph.D.
Professor of Biology and
Chairman, Natural Sciences Division
Carver Research Foundation
Tuskegee University
Tuskegee Institute, Alabama 36088
(334) 727-8124
(334) 727-8873 (laboratory)

Institutional Profile

Total enrollment	3,206
Undergraduate enrollment	3,007
Number of faculty members	346
Endowment (millions)	\$40
Annual budget (millions)	\$72

Student Tracking in Research and Prefreshman Programs University of Michigan–Ann Arbor

The University of Michigan–Ann Arbor is a public research institution. In 1992 the Howard Hughes Medical Institute awarded the University $1,400,000 for support of a program to (1) attract and retain students early in their academic careers by providing summer and academic-year laboratory research experiences in the biomedical sciences to first- and second-year undergraduates, as well as enhanced advising and tutoring; (2) provide upper-division biology students with in-depth research experience through a new "project laboratory" course offering open-ended investigations in genetics and molecular biology; (3) enhance the use of computer technology in science education for use in student tutorials and other purposes; and (4) upgrade equipment for instructional laboratories in such fields as microbiology, developmental biology, and physiology; and establish a new course in neuroscience for nonscientists.

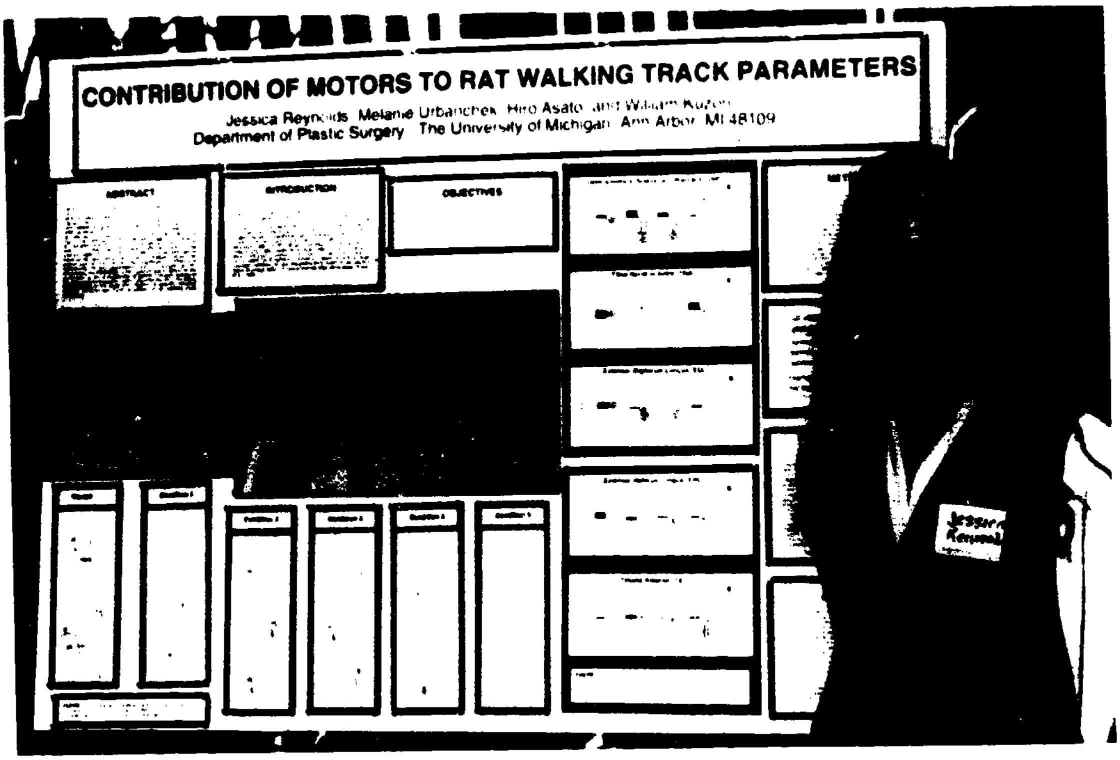
Research Partnerships

Prior to receiving HHMI funding, the University of Michigan piloted the Undergraduate Research Opportunity Program to increase the retention and improve the academic performance of underrepresented minority students at the University. The assumption was made that high attrition rates for underrepresented minority students are derived from their failure to become involved in the academic mission of the University. Therefore, students were given the opportunity to participate in research partnerships with faculty during the academic year and summer.

HHMI funding has enabled the program to expand its enrollment and has increased the number of research opportunities throughout the university. Projects are available in biomedical, biological, and allied health research.

The participants receive additional support through extensive peer advising and research peer groups. Groups of 20–25 students meet twice a month to learn about one another's research and to discuss controversial or timely biomedical issues. Graduate students, medical students, women scientists, medical researchers, and students in joint medical/doctoral programs are invited to speak. In addition, the sessions include workshops on time management and résumé writing.

Dr. Michael M. Martin, Associate Dean, College of Literature, Science, and the Arts, and HHMI program director, explained that the focus of the research program is on freshmen and sophomores, especially women and underrepresented minority students, who have an interest in science careers. Funding from HHMI directly supported 60 students during the 1993–1994 academic year.



Jessica Reynolds, an undergraduate at the University of Michigan, presents her award-winning poster.

Students have worked with faculty members in research laboratories at the University's Medical School, School of Nursing, School of Dentistry, Division of Kinesiology, and College of Engineering (bioengineering), at the Veteran's Administration Hospital, and at private biomedical laboratories. More than 350 faculty members sponsored students in their laboratories during the 1993–1994 academic year.

Student research projects span a wide range of topics—e.g., Lyme disease, the role of the immune system, and the psychology and neuroendocrinology of menstruation. Students are encouraged to present their results at national and local conferences. Jessica Reynolds presented a paper entitled "Contributions of Individual Motors to Rat Walking Track Parameters" at the Fourth Annual Conference of the American Society for Peripheral Nerves sponsored by the Albert Einstein Medical Center. Stephanie Donaton was invited to present a poster entitled "Role for the Hippocampus in Exercise-Induced Lengthening of the Period of the Hamster Rhythms" at the National Conference on Undergraduate Research. Allison Davis gave a paper at the same conference on her evaluation of the exercise component of a weight program.

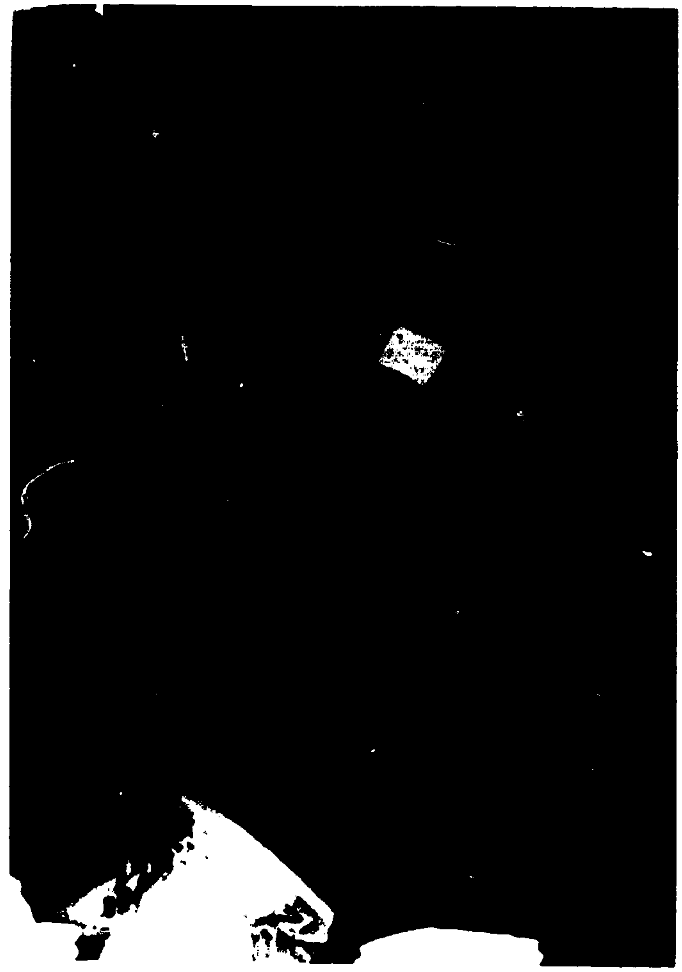
According to Sandra Gregerman, program coordinator, "the ability to offer paid positions to minorities and women so that they get to know what hands-on research is all about has been absolutely invaluable to the success of the program."

Tracking and Evaluating

To evaluate the effectiveness of the University's undergraduate research opportunities program, Ms. Gregerman, Ratnesh Nagda--a graduate research assistant, and their colleagues developed instruments to evaluate several aspects of the program: student retention to graduation, academic performance (including course selection patterns as well as grade point average), student attitudes toward learning and their own academic capabilities, the impact of the partnerships on faculty sponsors' attitudes toward women and minority students, and the operation of the program, indicating how service to students and faculty can be improved.

The experimental group included students who applied and were admitted to the program, and the control group included those who applied but were not admitted. Evaluation of academic outcomes has revealed encouraging preliminary results in regard to retention, grade point averages, and course selection patterns for students in the research program:

- Students who participated in the program had an attrition rate 32 percent lower than that of all underrepresented students in the University (13.6 percent vs. 20.0 percent).
- African American students in the program had an attrition rate 51 percent lower than African American students in the control group (9.2 percent vs. 18.6 percent).
- None of the white and Asian participants who had low grade point averages withdrew from the University; but 12 percent of those in the white and Asian control group did.
- Among all the program participants, the grade point aver-



DaRhon Connor, a Howard Hughes Summer Research participant, presents his research project "An Exploratory Study of Natural Products of Medicinal Value from Plants" at the spring research symposium. Mr. Connor is working with Dr. Peter Kaufman, Professor of Biology and Plant Physiology, in collaboration with the Warner Lambert-Parke Davis Pharmaceutical Company.

age was raised by 6 percent (2.58 vs. 2.73).

- African American students in the program had a grade point average 7 percent higher than African American students in the control group (2.69 vs. 2.51).
- The program seems to be having an effect on self-esteem, coping strategies, and expectations about academic performance, especially for the African American students.
- More of the underrepresented minority students than students in the control group indicated a feeling of support from the University.

The results of the survey were presented in June 1994 at the Seventh Annual National Conference on Race and Ethnicity in American Higher Education, held in Atlanta, Georgia.

Program Director

Michael M. Martin, Ph.D.
Associate Dean, Undergraduate Education
2522 LS&A Building
University of Michigan - Ann Arbor
Ann Arbor, MI 48109-1382
(313) 764-0322
(313) 764-2697 (fax)
MMARTIN@UM.CC.UMICH.EDU (Bitnet)

Institutional Profile

Total enrollment	36,228
Undergraduate enrollment	23,126
Number of faculty members	4,003
Endowment (millions)	$487
Annual budget (billions)	$1.8

Student Tracking in Research and Prefreshman Programs Williams College

Williams College is a private liberal arts institution in Williamstown, Massachusetts. In 1993 the Howard Hughes Medical Institute awarded the College $500,000 in support of (1) equipment for introductory biology laboratories and classrooms, and equipment for interdisciplinary biology programs in neuroscience, biochemistry, and molecular biology; (2) outreach activities, such as the expansion of a high school outreach program and development of an elementary school outreach program involving curriculum development; and (3) an expanded summer research program for undergraduates.

Why Track Students?

Two years after starting their program under a 1991 grant from the Institute, faculty at Williams College saw some intriguing developments that led them to begin formally tracking a select group of students.

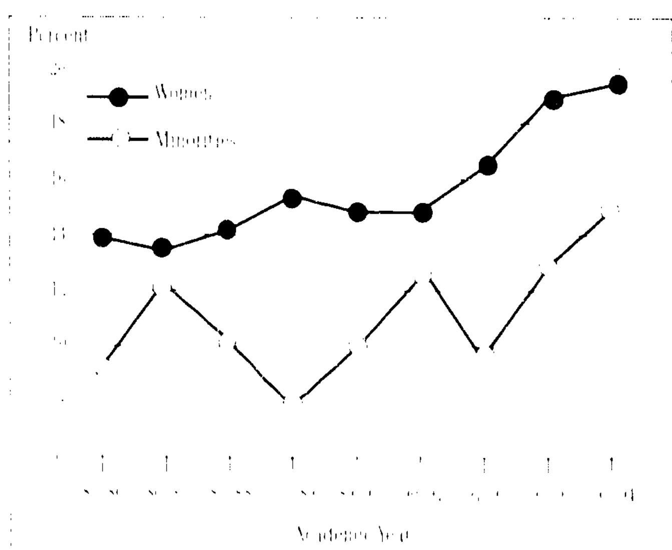
One was a linkage that had obviously developed among several of the activities. The names of the same students kept appearing on different activity rosters, suggesting that the program had succeeded in creating a support network for them.

The other was a dramatic rise in biology enrollments. Those for the introductory sequence had nearly doubled since the start of the program, and enrollments in upper-level biology courses showed similar growth. Retention was up, too, as reflected by increased numbers of students majoring in the sciences. The percentage increase of women and underrepresented minority students was the most striking.

The enrollment increases and the linkage among its activities indicated that the 1991 and 1993 programs might be doing what planners hoped they would do: recruit and retain women and underrepresented minorities in the sciences. Faculty therefore decided to track students in a prefreshman program, aiming to quantify the linkage and see if the programs were actually contributing to the enrollment increases.

"We have some really interesting indications," said Dr. Steven J. Zottoli, Professor of Biology and HHMI program director.

Science Majors at Williams College



Summer Science students Ramona Nicholson (left) and Elizabeth McCray (right) working with faculty member David Richardson in the chemistry laboratory.

THE CLERMONTS

"That's exciting. But as director, I'd like to know what's working and what's not working and how we can improve on it."

In seeking his answers, Dr. Zottoli is capitalizing on a discrete group of students that can easily be tracked: participants in the Summer Science Program for Minority Students directed by Olga R. Beaver, Ph.D. Professor of Mathematics, which has been strengthened and expanded by the 1991 HHMI grant. Each year, the Summer Science Program brings to campus 12 to 14 underrepresented minority prefreshmen who have been admitted to Williams and who are interested in science. For five weeks, these students are immersed in college life, attending classes in chemistry, mathematics, and English, as well as laboratories in biology, chemistry, and geology.

The chemistry component, for example, provides an accelerated exposure to the material covered in introductory chemistry given during the school year. Lectures on topics such as equilibrium processes are matched with discovery laboratory exercises on the same subject matter. The idea is to help students feel so comfortable on campus and in their studies that they will go on in both college and science. Other programs, such as a Math and Science Resource Center, help the students after they enter college.

Tracking the Summer Science students is new. Nevertheless, two factors appear essential to the effort's success: a select population of students that can be identified by name, and early planning of ways to collect data after graduation. In that regard, an interview with the graduating seniors may increase the effectiveness of tracking them.

The Math & Science Resource Center exemplifies the type of activity for which it is difficult to track student participation. The tutors there help more than 500 student visitors each semester with introductory courses in biology, chemistry, mathematics, and physics. Such programs typically do not register the names of participants, and students are often reluctant to volunteer information.

"The best you can do is get a survey report," Dr. Zottoli said. "The data are clouded by those who refuse to answer, and you can't tell who wasn't present and who refused to do the survey. So it's interesting information, but it's very limited."

The Summer Science students, whose identities are known, are more easily tracked, however. After these students start regular classes, their names can be checked against lists of those who do summer research, become tutors at the Resource Center, or participate in other science activities. For example over the past three years, 41 percent of the Resource Center tutors had participated in the Summer Science Program.

Because the Summer Science Program started in 1987, comparison data are available to determine whether HHMI-supported programs have increased the program's effectiveness in retaining underrepresented minorities in the sciences. The preliminary data are encouraging. Specifically, the percentage of underrepresented minorities at Williams College who have declared science as a major has increased from 9 percent during the 1985–1986 academic year to a current level of 14.9 percent.

"Tracking allows us to get an idea of the student involvement," Dr. Zottoli explained. "Since one of the goals of the program and the College overall is to try to recruit and retain minorities and women in the sciences, [the] Summer Science [Program] seemed like a good opportunity to assay whether that was actually happening."

Tracking this group of students has been very time-consuming. Time expenditures were high during initial data collection and have risen again while the data are being analyzed. The question now appears to be how to establish a meaningful database and develop a control group for comparison.

Benefits of Tracking

Although a formal analysis has not been completed, tracking of the Summer Science students has generated anecdotal evidence that, at the college-entry level, the program is attracting students to science and holding

Lauren Araiza, Greg Crowther, and Vy Bui (left to right) working in Dr. Daniel Lynch's laboratory.

SUE MEAD

them. The percent of Summer Science students going on to major in the sciences is now over 70 percent. The data have also suggested ways in which the program might be improved. One involves encouraging these students to participate in research.

The next level of the HHMI program due for tracking is the research experience, which includes both minorities and women. Said Dr. Zottoli, "What I'm getting from looking at these numbers is that we could probably do a better job of advertising [the HHMI program] to make sure that those students we attracted at the introductory level learned of these opportunities and were encouraged to enter into them."

For example, two students, Lauren Araiza and Vy Bui, who attended the Summer Science Program in 1993, were awarded research stipends the summer following their freshman year. Their research, conducted under the mentorship of Dr. Daniel Lynch, Assistant Professor of Biology, focused on studies that should help determine the function of plant membrane sphingolipids. The students first learned basic techniques in the extraction and identification of the lipid compounds.

Subsequently Ms. Bui helped design a project that focused on delineating the metabolic pathway of sphingolipid formation using radioactive serine, and Ms. Araiza began a transmission electron microscopic study of the effects of a mycotoxin, fumonisin, known to interrupt the sphingolipid pathway and cause degradation of plant tissue. These students were given an opportunity to participate in ongoing faculty research the summer before their sophomore year at Williams. It is hoped that this special experience will direct their future career choices toward science.

Dr. Zottoli hopes that tracking will ultimately indicate that HHMI-funded programs have helped the minority Summer Science students successfully pursue careers in science. Such a finding would be very significant to the program and to Williams College as a whole. Tracking those students may also provide some indication of how other students might benefit, although Dr. Zottoli admits that such generalizations are difficult to make. HHMI program benefits to the students as a whole, however, might be better assessed through enrollment figures, retention rates, and other data.

Dr. Zottoli cautioned that tracking data only provide indications of success and may even be misleading. If some participants go on to study law, would it indicate failure because they didn't go on in science? Or would it indicate success to change the outlook of a student who may later pursue a career in environmental law or other fields dealing with social issues related to the sciences? These issues need to be considered carefully in judging science education programs in general.

"That's really important, because one of the goals of the program and, I think, of any institution is science literacy," he said. "The problem with tracking in general [is that] you're led by the data. You may be missing other subtle things."

Tracking After Graduation

Qualitative data will be gathered when the Summer Science students leave Williams. The first cohort of students supported by HHMI programs will graduate in 1995. Surveys, questionnaires, and senior exit interviews are being considered for tracking. Whatever techniques are decided upon, they will be administered for the most part through the College's highly effective alumni tracking system.

"We keep central files on all our alumni," said Mary Ellen Czerniak, Director of Corporate and Foundation Relations. "For 95 percent of them, we have up-to-date addresses, and we stay in touch through an active alumni network. They provide us with information on where they're working, where they're going to school, and the advanced degrees they have earned."

Every three years, the alumni office sends out a questionnaire to update information in the alumni directory, and over 75 percent of the alumni respond. This survey, the central alumni database, and new address information sent by the post office when the quarterly alumni magazine is mailed all play key roles in the tracking system.

Tracking effectiveness is further helped by the strong commitment of alumni to stay in touch with the College through alumni organizations. When they graduate, each class elects a president and other officers responsible for maintaining contact among class members via the alumni magazine and in other ways. Over the past 15 years, a second-tier alumni network has been evolving with the development of affinity groups of minorities.

A mechanism for tracking the Summer Science students will be modeled on the alumni system. The mechanism may involve a questionnaire and interview before students leave campus and mail and telephone interviews afterwards.

Exit interviews for the seniors are being planned for 1995. Students would be asked specific questions such as which programs they participated in, what the deficiencies were, why they did not participate in some programs, which ones made them feel more comfortable, or what factors helped them decide to study and continue in science.

Follow-up questions would focus on student views of their undergraduate education as well as their experience since then. For example, students might be asked about their experience in graduate school and how it differed from their undergraduate research.

"The exit interview could be critical to developing a commitment in students to stay in contact with the college," Ms. Czerniak said. "That is where you need to tell these students, 'Your experience is important to us and it's going to help others who come after you, so would you be willing to share it with us and stay in touch during the next (few) years, keep us posted on what's happening?'"

The tracking situation at Williams College is unusual in having a pre-existing population of students to follow and a well-established alumni tracking system. But focusing on a select group of students and devising a postgraduate tracking mechanism would be useful for such an effort.

"Each institution is going to have its own problems to overcome with the numbers and the types of programs they have," Dr. Zottoli said. "Some of our experiences will give them ideas that will help."

Program Director

Steven J. Zottoli, Ph.D.
Professor of Biology
Biology Department
Williams College
Williamstown, MA 01267
(413) 597-2266
(413) 597-4116 (fax)
STEVEN.ZOTTOLI@WILLIAMS.EDU (Bitnet)

Institutional Profile

Total enrollment	2,056
Undergraduate enrollment	2,005
Number of faculty members	209
Endowment (millions)	$390
Annual budget (millions)	$73

Curricular Reform: How Well Is It Working? Bates College

Bates College is a private liberal arts institution in Lewiston, Maine. In 1991 the Howard Hughes Medical Institute awarded the College $900,000 for a program comprising (1) summer research opportunities, with support for individual student projects and collaborative faculty-student research; (2) major revision of the introductory curricula in biology, chemistry, physics, and mathematics that will involve the integration of these fields and enhancement of the laboratory research component of these courses; (3) development of the intermediate and advanced biology curricula, with new courses in biophysics, biopsychology, biochemistry, and other relevant areas; (4) the acquisition of teaching and laboratory equipment and library resources to implement the new curricula; and (5) establishment of outreach activities for students, especially those from underrepresented minority groups and from rural Maine high schools. In 1993 Bates College received an additional grant for $500,000.

The Effects of Curricular Reform

As part of its HHMI-funded program, Bates College set out to revise its science curricula, with the goal of encouraging students to do more hands-on science earlier in their academic careers. Since 1991, introductory courses in biology and chemistry have been revised, a biological chemistry major has been added, the rest of the biology core curriculum has been upgraded, and changes for introductory physics are under way.

How well is curricular reform working at Bates? "It's working better than we could have hoped," said Dr. Martha A. Crunkleton, Vice President for Academic Affairs, Dean of Faculty, and HHMI program director. "The greatest strides have been made in biology," she said, "and we're having really explosive growth in terms of biological chemistry majors."

College officials had expected perhaps two or three students to declare a major in biological chemistry during 1993–1994, the first formal year of the major. Year-end estimates, however, placed the figure between 15 and 20.

The number of students taking introductory biology has grown, too. "We've seen this enormous increase in biology enrollment, and that's a national trend, so I can't tease out how much is due to the effort that goes on in our first-semester course," said Joe Pelliccia, Ph.D., Associate Professor and Chair of the Biology Department. But, he added, "we've doubled the number of majors in a three-year period. I'd like to feel we're somewhat responsible for that, but I have no way of knowing."

Students John McPartland, Priya Sudarsanan, and Patrick Wintrode (left to right) conduct experiments in a hands-on biochemistry laboratory at Bates College.

PETER SCARPACI

Qualitative data suggest that science curricular reform is working with Bates students. A year after a reformed course was introduced for all students taking introductory biology, course evaluations were the highest ever. This and other revised biology courses seem to be retaining more women, minority students, and students from poor rural areas of Maine. A similar demographic trend has developed in chemistry following the appearance of revised courses in biochemistry and introductory chemistry.

The Chemistry Department has traditionally had a problem attracting women majors, but almost all the students that declared as chemistry and biological chemistry majors in 1993–1994 have been women, according to Dr. T. Glen Lawson, Assistant Professor of Chemistry.

The HHMI grant has helped the College to expand research opportunities for students, purchase laboratory equipment, and fund departmental workshops where faculty have worked out curricular revisions. These functions, Bates officials say, have contributed greatly to the success of curricular changes in science. The grant also furthers the reform effort by supporting a laboratory instructor for biology and chemistry, who started in August 1992, and a neurobiologist, who started in the fall of 1994.

Student Research Stimulates Curricular Reform

Over the past three summers, the HHMI grant has funded research opportunities for 50 Bates students, substantially increasing the number of science students working with faculty. The expanded number of students working in laboratories has, in turn, stimulated the drive for curricular reform. This has produced a reciprocal relationship: as students do more research, they become better researchers and better students. Faculty have recognized this phenomenon, and many are now including student-assistant components in their research grant proposals. In addition, they have sought to broaden student access to research by bringing it to more of the lower-level courses.

"The summer research work certainly shaped the faculty's thinking about what they were doing in introductory courses," Dr. Crunkleton said. "For us, that has been curricular reform, because the faculty have started looking at how to create student research experiences in all the introductory courses."

A key to moving faculty toward curricular reform has been getting them to meet regularly to talk about it. Faculty tend to discuss traditional business at departmental meetings, not what they are trying to accomplish in revising their courses. To promote the latter kind of discussion, Dr. Crunkleton has used HHMI funds to support off-campus weekend workshops where faculty can have time to talk over curricular changes.

The biology faculty have participated in three of these workshops. One issue they wrestled with was whether the research experience available to students in small, elective upper-level courses should be incorporated into large introductory-level courses. If so, it would mean dramatically reducing the content of those courses. Out of these often difficult discussions came the decision to revise the four core biology courses to include more research activities.

The chemistry faculty explored curricular issues at a similar workshop. The talks generated ideas for revising introductory chemistry lectures and led to changes that have allowed the department to operate more smoothly. Faculty are working together better and are more willing to share their ideas about curriculum, research, and related matters.

"Those conversations are the ones that are really hard to have," Dr. Crunkleton said. "I would encourage people who are starting the curricular reform process at other schools to make sure they allow time for the faculty to get together and ask those basic questions."

Curricular Reform in Biology

In biology, curricular reform has focused on bringing more discussion into lecture classes and using an investigative, rather than a demonstrative, approach to laboratories. The PI—principal investigator—system mimics the scientific process, emphasizing the use of research teams and quantitative and writing skills.

In this system, groups of four students are assigned to four laboratory projects over a semester, with group members rotating as the principal investigator. They learn a new research technique one week, then design an experiment to answer some question using that technique. After they collect the data, the principal investigator drafts report in the style of a scientific paper, including references. The draft is circulated through the group for peer editing, and then the principal investigator writes a final draft and gives both drafts to the instructor for a critique and grade. Biology writing assistants are students trained by the department and the College's Writing Workshop to assist with scientific writing.

Karen Lecomte, who returned to college after 17 years to major in biopsychology, took a reformed version of Introductory Biology 101, followed the next semester by a traditional version of Biology 102. Biology 101, she said, involved more discussion and presentations by students, who were evaluated by a combination of multiple choice and short-answer questions and half-page essays.

In the revised 101 laboratory, Ms. Lecomte and her research group used the crustacean *Daphnia*, whose heart is visible through its shell, to design experiments to test the effects of caffeine and alcohol on heart rate. The team formulated hypotheses, decided what to measure, and designed the experiments. The principal investigator assigned research tasks and recorded and compiled the data.

Ms. Lecomte did equally well in both classes, but it was Biology 101 that motivated her to go on and do more in biology. "Biology 101 really clinched it for me," she said.

The success of a pilot course of reformed Biology 101 helped persuade the Biology Department to extend the curricular reform program to the entire course and to three others required of biology majors: Plant and Animal Biology, Cellular and Molecular Biology, and Population Ecology.

Even though 75 percent of the 340 students who took the first two required courses are not going to be science majors, Dr. Pelliccia said, they are getting a good exposure to how science is done in the real world.

Curricular Reform in Chemistry

In chemistry, curricular reform has followed a two-pronged approach, expanding research opportunities for students in biochemistry and shifting to more project-oriented laboratories, along the lines of the principal investigator system, in introductory chemistry and other courses.

During 1993–1994, the College began offering a biological chemistry major, using existing courses in biology and chemistry. To ensure that they get research experience, a senior research thesis is required of these majors. They start doing research in their junior year and continue it over the summer and often into their senior year as a senior thesis.

Dr. Lawson had already expanded research opportunities for biochemistry students by developing laboratories for the two-semester biochemistry sequence, which formerly had none. Further research opportunities will be available to upper-level students in the winter of 1995, when he and Dr. Pelliccia will teach a course focusing on nucleic acid biochemistry and molecular biology.

The increasing number of biochemistry offerings with research opportunities seems to have piqued student interest. An estimated 1₀ to 20 students have declared a biological chemistry major. And a large percentage of students in first-year biology and chemistry courses, where enrollments are rising, have indicated that they would probably major in biological chemistry.

The quality of the research opportunities in many science courses is changing. The advanced course in nucleic acid biochemistry and molecular biology will be very project-oriented. And in the winter of 1995, there are plans to switch the second-semester biochemistry laboratory to a project-oriented approach that will include perhaps just two projects each semester. Students will plan and carry out the purification of a protein produced from a cloned gene in a bacterium and perform an analysis of some of the structural features of the protein. They will also design and assemble a metabolic energy-producing system capable of supporting a reconstituted energy-requiring pathway. Others will purify and chemically identify the major species of carbohydrates found in selected fruits and vegetables.

Although traditional laboratories have always been small, one-week exercises, at Bates almost everyone in biology and chemistry is moving away from that approach, even in the first-year courses--a sign of significant reform.

The laboratory for introductory chemistry has changed from one-week experiments to three-and four-week modules. Students help to plan an experiment from a selected area such as biochemistry, geochemistry, or forensic chemistry. Replacing the traditional reports, which students have found to be tedious and of limited educational value, are modified reports that emphasize problem-solving, meaningful calculations, and articulate writing. Fewer reports will be required.

A revised introductory chemistry lecture, which will be introduced in the fall of 1994, aims to stimulate the students' interest by presenting the basic principles to be learned in a series of chemistry mini-courses. Members of the chemistry faculty will discuss their area of specialty, using real-life context to explain the principles that introductory chemistry students need to learn.

The curricular reforms in chemistry appear to be working. The longer experiments appear to be more fun and, because students have to think through the experiments in planning them, they retain more of what they learn. The laboratories have been designed to be more user friendly and less intimidating; they offer more opportunities for students to interact with their peers and faculty.

Students also seem to prefer the reformed curriculum in biology. In evaluating the revised Biology 101, a student wrote, "The writing is hard, it's a lot of work, but it made me think about what I was doing."

Program Director

Martha A. Crunkleton, Ph.D.
Vice President for Academic Affairs and Dean of the Faculty
Bates College
Lewiston, ME 04240
(207) 786-6066
(207) 786-6123 (fax)
MCRUNKLETON@ADM.BATES.EDU (Bitnet)

Institutional Profile

Total enrollment	1,599
Undergraduate enrollment	1,599
Number of faculty members	172
Endowment (millions)	$100.9
Annual budget (millions)	$52

Curricular Reform: How Well Is It Working? Carnegie Mellon University

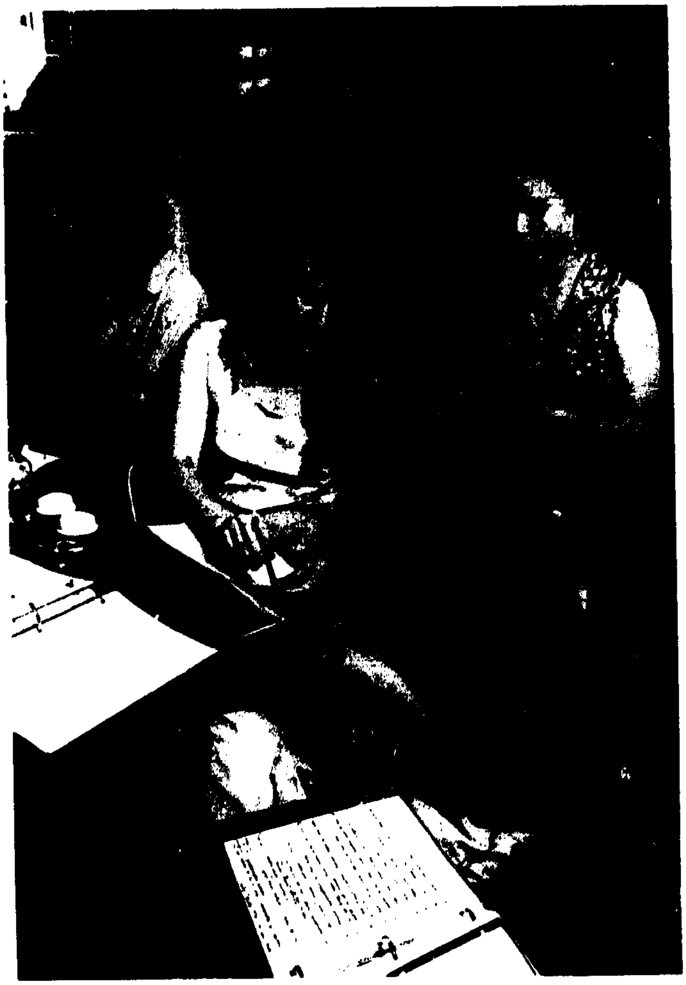
Carnegie Mellon University is a private research institution in Pittsburgh, Pennsylvania. In 1989 the Howard Hughes Medical Institute awarded the University $1,200,000 to (1) encourage science students, particularly women and underrepresented minority students, to identify research opportunities and plan careers in the sciences through faculty mentorships, research projects, and training; (2) provide new curricula and training opportunities in computational biology and chemistry; (3) provide advanced computer training for facul··· (4) obtain computer and laboratory equipment for the new curricula; and (5) develop outreach initiatives for high school teachers, particularly from schools with a large minority population.

Setting the Stage

Carnegie Mellon University has pioneered a new curriculum to integrate computers into its biology and chemistry courses. Drawing upon its strength in computer science, the University has created an interdisciplinary curriculum in computational biology and chemistry. The underlying goal is to provide a national model to meet the growing demand in academia and the pharmaceutical and biotechnology industries for scientists with advanced computer skills. Student reaction, as measured in course evaluations, has been so favorable to early reforms in upper-level courses that at least six biology and chemistry courses at advanced and introductory levels have been created or revised over the last three years.

The stage for these curricular reforms was set in advance. With HHMI support, a new Computer Training Center was built and equipped with advanced computers in 1990. Other antecedents to reform supported by HHMI were the provision of faculty release time for the development of new courses and research opportunities for undergraduate biology and chemistry majors. Finally, advising and mentoring programs were established to ensure that each major in the biological sciences received guidance by the sophomore year in course selection, career counseling, and research opportunities.

Students in the sciences at Carnegie Mellon are participating in individual research projects under faculty guidance. Special attention has been paid to recruiting women and minority students for research experience. Underrepresented minority students who majored in the biological sciences were assigned mentors as early as the freshman year. According to Dr. Susan Henry, Dean of the Mellon College of Science and HHMI program director, the creation of a new interdisciplinary curriculum



Undergraduates David Cassarino, Patrick O'Brian, and Cena Myers (left to right, back row) and Marta Lipinski, Paula McKinney, and Anna Sokac participate in biological research projects.

"could not have been undertaken without an infrastructure in place to guide and assist the students."

The New Curriculum

The cornerstones of the new curriculum are two new upper-level courses in computational biology and chemistry, first offered in 1991. Enrolling in one of these classes can lead to a Bachelor of Science degree with a concentration in computational biology or chemistry, provided the student has taken a combination of several computer science and mathematics courses above and beyond what is required for the science major alone.

One of the new courses, Computational Biology, covers a range of applications of computers to biology and medicine. It focuses on analysis of protein and nucleic acid sequences, plotting and fitting techniques, simulations of biological processes, multivariate statistics, and biological imaging. "Emphasis is placed on writing computer programs, a skill that will give them great versatility in computational biology," said Dr. Robert Murphy, an associate professor of biology, who designed the course and has spearheaded many of the curricular reforms.

The other upper-level course, Computational Chemistry, explores numerical methods, multivariate statistics, simulation of chemical, physical, and biological processes, and molecular modeling using three-dimensional graphics. As students learn molecular modeling, they gain the skills to manipulate the graphics in real time by using their knowledge of graphical languages.

Other New Computer Courses

The new upper-level courses have stimulated the development of three courses or minicourses: Introduction to Computational

Biology, Introduction to Computational Chemistry, and Introduction to Computational Molecular Biology. These courses cover many of the same topics as the upper-level courses but do not require students to learn programming skills. The courses are so interwoven that they include many of the same lectures.

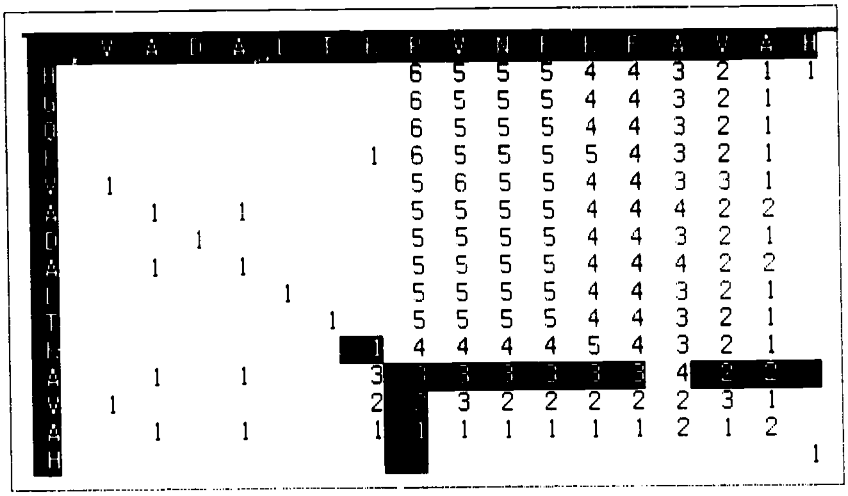
One common topic is the computer analysis of nucleic acid sequences. After being given a computer file containing nucleic acid sequences without any identifying information, students use software to assemble the sequences into a gene and match this unknown gene with existing national databases to determine the gene's identity and the protein it encodes.

They also characterize the degree of homology between their gene and those genes already entered into the databases. For example, students may find that a gene they were given from yeast has regions that are homologous to those in a gene from *Drosophila melanogaster*. Katya Donovan, one of the first students in the Introduction to Computational Molecular Biology mini-course, who entered a doctoral program in biochemistry at Johns Hopkins University in the fall of 1994, views the skills she developed as "essential for helping me proceed toward my graduate work."

In a departure from the way most computational applications are taught to beginners, Dr. Murphy—who teaches computational biology at the advanced and introductory levels—has created a computer program to help his introductory-level students understand better how the sequencing program operates. Rather than merely running the sequencing program and obtaining the output, his students benefit from a program he wrote that illustrates graphically how the computer searches for similarities between nucleic acid sequences. "My program is like a little viewer into what is going on inside the computer when a sequence comparison is operating. Normally you would not see any of these functions," said Dr. Murphy.

Computers are also being used in a two-semester laboratory course required of biological sciences majors in their junior year. "The computers are great tools to expand student horizons and serve a vital function in analysis of experimental data," says the instructor, Dr. Linda Kauffman, Senior Lecturer, Biological Sciences. Having completely revised her course to take advantage of the computers, she has created a database to catalogue DNA sequences of all the mutant strains that students produce in the laboratory. "The database allows us to create an atmosphere of continuity each year the course is taught, because students from one year can compare and match their sequences with those from pre-

The figure represents a sample output screen from a program designed to show introductory students how sequence comparisons are performed (see text). Stretches of sequence from two related proteins are shown across the top and down the left side. As a student uses the program, it shows each step in the comparison between the sequences by the dynamic programming method. At the point where this screen was captured, the program was examining the sequences down and to the right of the first K in the top sequence. It searched the highlighted partial rows and columns to find the highest numerical value, which equals the maximum numbers of matches that can be obtained from that location onward. In this case, the best score that was found is the 4 that is unhighlighted. Thus, the best alignment is obtained by skipping the sequence PVNFKF (top) and resuming alignment with AVAH.



vious years," observed Dr. Kauffman.

Measuring Success

Carnegie Mellon has not undertaken a full-scale evaluation of the impact of its curricular reforms, but there are many measures of success. Each year more students enroll in the advanced and introductory-level courses in computational biology and chemistry. When they finish the courses, students have expressed their enthusiasm in evaluation forms by giving high ratings for course content and clarity of instruction. The number of students majoring in biological sciences has more than doubled, surging from 30 in the early 1990s to 70 in 1993–1994. Thus far, 12 students have graduated with a bachelor's degree in computational biology or chemistry. All have headed for graduate or medical school, or private industry.

Dr. Henry is eager to conduct a formal evaluation of Carnegie Mellon's curricular reforms, yet she is apprehensive about measuring the impact of one or two courses in isolation. She stated, "We anecdotally hear from students how much a course meant, but the impact of any course cannot be felt or known by students immediately afterwards. We must look more globally at the impact of our curriculum, which is probably felt over the initial phases of their career....We need better ways to follow our students' progress for several years and solicit feedback from them at regular intervals to determine the impact, not just of one class, but the entire curriculum on their overall problem-solving skills."

Among the first to graduate with a bachelor's degree in computational biology was James Mace. He is currently enrolled in a doctoral program in biochemistry at the University of

California–San Francisco, where he is a Hughes Fellow in the laboratory of Dr. David Agard, Investigator, Howard Hughes Medical Institute.

Mr. Mace sees a strong connection between his concentration at Carnegie Mellon and his current research in protein crystallography. Computer imaging is especially useful in visualizing the structural mutations he has produced experimentally in α-lytic protease, an enzyme that cleaves peptide bonds. He is investigating the function of structural mutations in order to design proteases with a desired substrate specificity. He feels that his concentration at Carnegie Mellon "helped to prepare me for my doctoral research by enhancing my programming skills....It was a stepping stone to the work that I am now pursuing."

Program Director

Susan A. Henry, Ph.D.
Professor, Biological Sciences, and
Dean, Mellon College of Science
Carnegie Mellon University
4400 Fifth Avenue
Pittsburgh, PA 15213-3890
(412) 268-5124
(412) 268-3268 (fax)
SH4B@ANDREW.CMU.EDU (E-mail)

Institutional Profile

Total enrollment	6,642
Undergraduate enrollment	4,342
Number of faculty members	548
Endowment (millions)	$405
Annual budget (millions)	$336

Curricular Reform: How Well Is It Working? University of California–Los Angeles

The University of California–Los Angeles is a public research institution. In 1992 the Howard Hughes Medical Institute awarded the University $1,300,000 to support (1) establishment of departmental centers to provide advising, tutoring, and science career counseling for introductory-level students in biology and the physical sciences, including women and underrepresented minorities; (2) enhancement of the introductory-level biology course to include new experiments, and creation of a new undergraduate neuroscience laboratory; (3) creation of a center for research on teaching to involve science faculty in undergraduate teaching and curriculum development; and (4) opportunities for students from Los Angeles high schools with significant minority enrollments to join University research laboratories in science and engineering, and to participate in ongoing workshops in educational and career development throughout the school year.

Responding to Change

In California a deeply eroding tax base has triggered a fiscal crisis in the state's higher education system, resulting in substantial changes such as large-scale restructuring of academic departments and the departure of hundreds of senior faculty through early retirement. At the University of California–Los Angeles (UCLA) campus, a grant from the Howard Hughes Medical Institute is supporting efforts in life sciences departments to capitalize on the atmosphere of change and to pursue longer-term objectives with a degree of certainty about the future.

It is estimated that the University of California system overall will lose more than 900 senior faculty through a voluntary retirement program designed to cut costs. Dr. Frederick Eiserling, Dean of Life Sciences at UCLA and a microbiologist, anticipates that this will mean at least a 10-percent reduction in the number of faculty from 1990. On top of this, he adds, is the prospect of a 20-percent budget reduction from 1990 levels of funding.

The fiscal reductions in California initially dampened the momentum for revising science and mathematics curricula, primarily because the limitation of expenditures for instructional equipment has discouraged faculty from putting much effort into updating courses. As Dean Eiserling observed, "We knew there were things we should be doing in terms of curriculum reform, but you can't reform the curriculum unless you begin to change courses, and that requires an investment of faculty time and new equipment."

Reforming the Science Curriculum

The goal of the curriculum reform initiatives at UCLA is to integrate the life sciences and the physical sciences, particularly chemistry. One impetus is the large number of life sciences majors who turn up in introductory chemistry courses, sometimes accounting for 60–70 percent of the students in class—yet the courses are taught for chemistry majors. Not surprisingly, introductory chemistry is one of the traditional "filter" courses that can discourage students from continuing in the life sciences.

Other approaches, such as interactive video learning and team teaching, which have already have proved successful in the introductory chemistry course, are the basis for changes in the introductory biology laboratory, which reaches over 800 students a year. Faculty members are developing computerized laboratory exercises, called modules, that allow students to explore for themselves concepts of basic biology.

With one module, students will be able to observe experimental procedures before undertaking them in their laboratories. The module combines high-quality images, interactive and investigative computer-based learning with traditional experimental procedures. With another module, Mendelian Inheritance, students will learn about genetics by comparing mutant and wild-type flies. They will first observe techniques to make genetic crosses with flies and then perform crosses with live flies.

According to Dean Eiserling, the Institute's grant and support from other sources have stimulated a number of faculty to develop new courses. For example, the neuroscience faculty is focusing on laboratory development, particularly in upper-division courses that require new instrumentation and computers. An upper-division independent study laboratory, the Bio-Computation Lab, is designed expressly to retain students in biology programs by providing opportunities to do research involving simulating, modeling, and visualizing biological systems.

The impact of the curricular changes in biology will be studied by cognitive psychologists, who will compare the similarities and differences between novice students and expert faculty in biological problem solving in order to identify the approaches that are more appropriate for the students. For each teaching module, the psychologists will analyze how students structure knowledge in each of the areas in order to guide the development of the module. Similar assessment techniques have become standard components in many

UCLA grant proposals for science curriculum reform.

Dean Eiserling commented that the budget cuts have accelerated what would have been the natural course of events at UCLA. Eleven departments from both the medical school and the college already had a single recruitment brochure with 160 faculty at the graduate level who grouped themselves into 12 "research affinity groups," none of which is named after an existing department. Further, the faculty now describe themselves in terms of their research interests, e.g., cell biologists, developmental biologists, immunologists—rather than as members of a particular department.

UCLA life science departments have gotten closer together because the budget cuts required administrative reorganization, Dean Eiserling notes. For example, cell and molecular biology, integrative biology, and physiological science now have a single administrator and have combined their student advising. "If we bring in microbiology and biochemistry over the next few years, we're going to have a very different landscape on this campus than when it was founded 75 years ago," he said.

Dean Eiserling foresees the next step to be the development of undergraduate curricular units that are based not on department location but on faculty expertise. In the life sciences, he noted, the distinctions between the departments have blurred so that it has become difficult to distinguish them. He points out that this is not unique to UCLA; it is occurring at academic institutions throughout the nation as they respond to the increase in interdisciplinary research and financial exigency.

Attacking Student Attrition

Undergraduate curricular reform, as well as extracurricular support activities developed by the College of Letters and Sciences, the School of Medicine, and the School of Engineering and Applied Sciences, includes efforts to counteract the discouragement experienced by minority students. Overall, the UCLA student body reflects the ethnic and cultural diversity of the population in southern California, where the traditional minority groups have merged in recent years to become the majority. But this diversity is not evident among life science graduates, where there is a high attrition rate among underrepresented minorities. In this instance, the minorities that are underrepresented are primarily African American, Hispanic, and Native American.

The UCLA Division of Life Sciences includes the departments of biology, microbiology, physiological science, and psychology, which has a substantial neuroscience component. In 1993–1994 these departments had a combined total of approximately 5,100 undergraduate majors. Attrition among life science majors is a concern generally: of all the students who start their freshman year as a life science major (25 percent of whom are underrepresented minorities), only about 50 percent were graduating with a degree in life sciences in five years or less. In 1987 underrepresented minority students were graduating at an alarming 8 percent. Further, the number who continue their studies in graduate school approaches zero.

UCLA statistics were showing an especially high drop-out rate among these students between the first and second years, and between the second and third years, with students reporting that they have been discouraged by lower-than-expected grades, lack of a support network, and an inability to envision themselves in a science career.

The Center for Academic and Research Excellence is a part of the Division of Life Sciences. It provides approximately 100 underrepresented minority science students with special academic counseling and other academic and social support activities designed to encourage them to continue in science. The center is directed by Dr. Elma Gonzalez, a biology professor, who also is Director of Undergraduate Special Programs in Science in the office of the Provost of Letters and Sciences, which is responsible for all 24,000 undergraduates at UCLA. In the three years since the HHMI grant was received, graduation rates for minority students have increased by 10 percent each year.

According to Dr. Gonzalez, the center coordinates academic resources and funds from different sources that may be targeted to meet different needs. What the students need most, she said, is specialized counseling, and financial aid such as stipends for student research in faculty laboratories. The center administers the Howard Hughes Honors Undergraduate Research Program. In 1993, the first summer of operation, nine students were selected for the program on the basis of their academic merit, prior research experience, and their potential for success in graduate school as well as on the basis of a 600-word essay.

The students' majors ranged from biochemistry to psychobiology. They conducted research on such topics as epilepsy, pediatric HIV, memory and vision, and neuromuscular plasticity and space flight. The summer fellows attended workshops to learn about advanced library search techniques and how to prepare for the Graduate Record Examination, and the Bio-Computation Lab was available for their use. A year later, six of the nine fellows were continuing UCLA students. Of the remaining three, two went on to medical school and one began Ph.D. studies in biochemistry. Thirteen undergraduates were selected to participate in this program in 1994.

The Institute's grant contributes to UCLA's Academic Advancement Program, a tutoring program that offers academic counseling to undergraduates, including underrepresented minority students. The Academic Advancement Program has now assigned two full-time tutors to the life sciences. Dean Eiserling points out that external support, such as that provided by the Institute, has helped to direct additional institutional support to the program.

Recognizing that historically underrepresented minority students often are lost to science at an early age, UCLA also uses Institute funds to establish a precollege outreach program known as Science and Mathematics Achievement for Research Training, which comprises a six-week summer program and a series of school-year "Saturday Academies." These programs currently involve 65 minority students from the 8th grade to the 11th grade. Thirty of the students focus primarily on science and are supported by the Institute grant. The other students are more involved in engineering.

The summer portion of the program includes precursory courses in geometry, advanced algebra/trigonometry, and precalculus with computer applications; SAT preparation; biotechnology research; and interdisciplinary studies of the environment that draw from biology, chemistry, mathematics, and social science. Topics for the Saturday activities include genetics and probability, simulating environmental problems, and career exploration.

The primary goals of the outreach program are to increase the participation of underrepresented minority students in college preparatory mathematics and science and to encourage student commitment and excellence through early exposure and training in scientific research.

Another important objective is to buttress students' aspirations and encourage their abilities. According to Enrique Ainsworth, Director of the UCLA Center for Minority Engineering Programs, helping to strengthen students' confidence and sense of achievement is crucial to improved academic performance.

Early signs are that the program is succeeding. Of the 30 Institute-supported students participating in the 1993 summer program, 50 percent reported getting an A in fall semester mathematics, and 40 percent a B. In biology and chemistry, close to 70 percent report grades of A and 30 percent achieved a B. All 30 students are enrolled in college preparatory course sequences and are taking challenging mathematics and physics courses.

Program Director

Frederick A. Eiserling, Ph.D.
Dean, Life Sciences
College of Letters and Science
1312 Murphy Hall
University of California–Los Angeles
Los Angeles, CA 90024
(310) 825-4959
(310) 825-9368 (fax)
FREDE@LANDS.SSCNET.UCLA.EDU (Bitnet)

Institutional Profile

Total enrollment	32,866
Undergraduate enrollment	22,892
Number of faculty members	1,633
Endowment (millions)	$429
Annual budget (millions)	$1.6

Assessing Outreach Programs North Carolina State University

North Carolina State University is a public research institution in Raleigh, North Carolina. In 1992 the Howard Hughes Medical Institute awarded the University $1,000,000 to support (1) summer and academic-year research experiences for undergraduates on campus and in government and private industrial laboratories in neighboring Research Triangle Park; (2) outreach to high school science teachers, particularly those serving rural and minority students, to include interdisciplinary laboratory workshops in biology, chemistry, and physics, development of exercises and materials for classroom use, and laboratory kits and equipment loans to enable teachers to implement the new curricula in their classrooms; and (3) curricular revisions such as integration of biology, chemistry, and physics in introductory courses and a new laboratory in biochemistry and molecular biology.

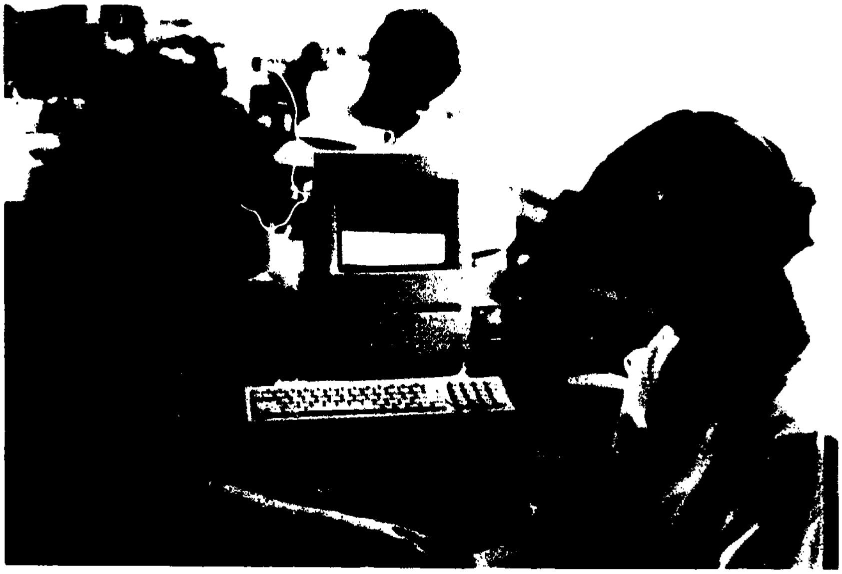
Rural Outreach

With HHMI support, a variety of programs have been initiated at North Carolina State University by faculty members and students from the College of Agriculture and Life Sciences and the College of Physical and Mathematical Sciences. Many partnerships have been developed with schools throughout North Carolina, and special efforts are being made to reach rural school districts. A large number of middle and high school students, teachers, and administrators have been involved with the project. The goal of this partnership has been to enhance the level of science instruction by training teachers and to increase the interest in science by working directly with students.

Dr. William C. Grant, Associate Provost and HHMI program director, said, "The best aspect of the HHMI funding has been the opportunity to influence young people by motivating them to enjoy science. The methods used in training teachers focus on student-centered learning techniques. The introduction of high-technology equipment has greatly enhanced interest in the program."

The science programs operate in North Carolina's rural school districts, the majority of which are unable to fund science education technology without additional assistance. As Judy Powell, program coordinator, points out, "Many schools would not be able to purchase the equipment. One of the unique aspects of this program is its continued support for the teachers. We not only train them in the use of technology in their classrooms, but we provide the equipment and university personnel to assist them."

The first teacher training workshop was held at the Univer-



Kathy Balley and Miles Bule, teachers in the North Carolina State University HHMI-supported science outreach program, investigate the correlation of heart rate and muscle temperature during exercise, using computer-integrated probes.

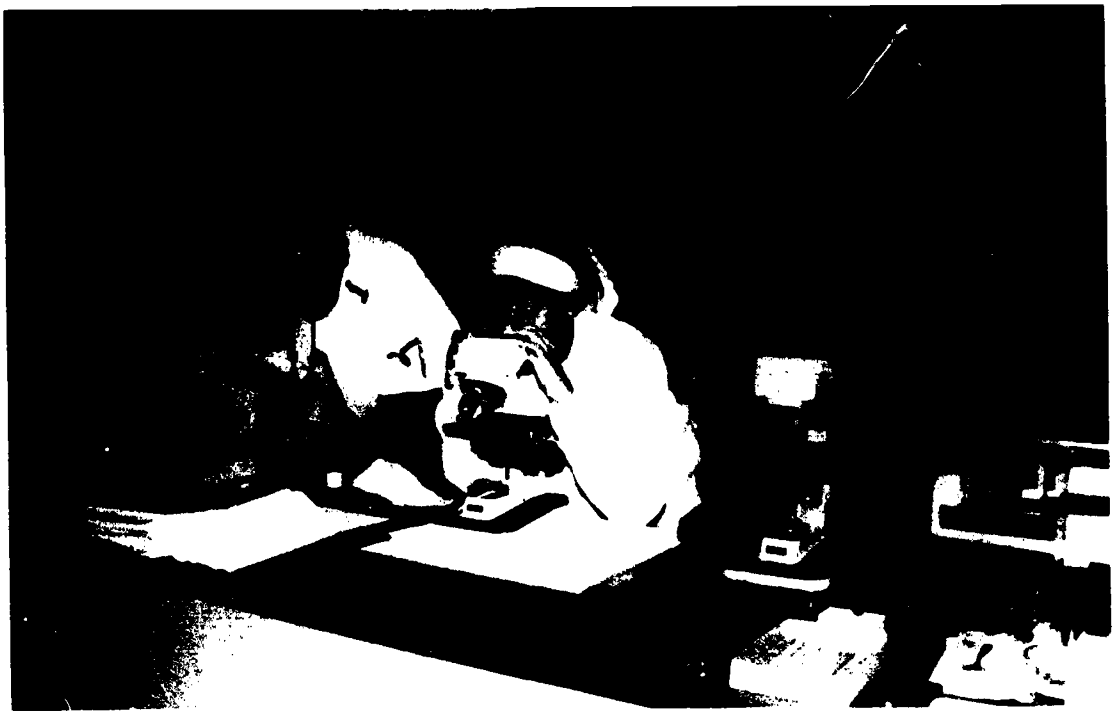
sity for two weeks during the summer of 1993. Participants included 12 high school chemistry, biology, and physics teachers from rural high school districts in southeastern North Carolina that have a high concentration of underrepresented minority and economically disadvantaged students. The teachers also attended two short workshops during the school year.

Ten of the original teachers were joined by five additional teachers from participating schools for a second two-week institute in the summer of 1994. One high school teacher commented, "My students' enthusiasm was remarkable. They were so eager to get involved. One of my students said, 'I can't wait to get to biology class.' It was amazing to see the 'light bulb' click and stay on. The interest was unbelievable."

During the workshops, the teachers learned to use such resources as a video microscope, a spectrophotometer, electricity kits, light kits, and computer-integrated laboratory equipment. They also received advanced instruction in teaching strategies and participated in discussions focusing on constructivism, the learning cycle, and student learning styles.

The teachers developed four learning modules on force, energy, electricity, and light, using microcomputers with laboratory probes and other pieces of equipment in the program. Two interdisciplinary modules, "Body at Work" and "Food and Energy," were tested in the summer and finalized for instruction during the 1993–1994 school year. The modules included investigations based on topics in physics, chemistry, and biology.

For example, one of the labs asked the student how exercise affects heart rate, respiration, and body temperature. Answer-



Students in an advanced biology class at Triton High School, Harnett County, North Carolina, study cell structures using microscopes provided through the HHMI-supported outreach program.

ing this question combines concepts of biology, chemistry, and physics. The students measured their heart rate, CO_2 respiration, and muscle temperature before and after exercise, using computer-controlled thermometers, heart rate monitors, and pH meters. They could observe and control their responses with the computers. The experiment displays in immediate personal terms the effect of abstract concepts that are part of the biology curriculum.

Each module included pre-assessment questions, introductory laboratory activities, one or more major laboratory investigations, and a post-assessment of the concepts. All were discovery learning–oriented for the students. Teacher materials were provided to aid in student preparation, development of concepts, and teacher preparation. During the 1994 summer institute, the teachers developed additional activities that were shorter in length and were directly linked to the new North Carolina science curriculum, which is process oriented. These additional modules will be edited and field tested during the 1994–1995 school year.

Ms. Powell transported the equipment by van to the individual schools. The materials were loaned to each school for four weeks, divided into one- to two-week intervals throughout the school year, at times chosen by the teachers during the summer institute. A total of 1,508 high school students used the equipment during the 1993–1994 school year. This number will increase with added teachers in the program. Dr. David Haase, Associate Professor of Physics, and Dr. Charles Lytle, Professor of Zoology, who are co-directors of the precollege science outreach program, visited the rural schools to observe the program and seek support from principals and school administrators.

Other Outreach Activities

The HHMI program has reached students and pre-service and in-service teachers. Activities funded by the Institute include presentations on the use of computers in the biological sciences to the North Carolina Student Academy of Science; a presentation on the outreach program to the North Carolina Science Teachers Association; classes for pre-service science teachers on technology in the laboratory; preliminary meetings to organize a science/mathematics consortium for public schools in northeastern North Carolina; working with the Site-Based School Management group of the North Carolina State University School of Education and Psychology; consultations with local schools for developing science technology; support for the Physics on the Road demonstration program involving over 10,000 students throughout North Carolina; and coordination of the Science Teacher Workshop held by the College of Agriculture and Life Sciences.

The HHMI program is supported by The Science House, an outreach program of the College of Physical and Mathematical Sciences at North Carolina State University. Its purpose is to motivate K–12 students to study science and mathematics, and it emphasizes hands-on learning. The Science House is a partnership between NCSU and North Carolina public school teachers. The faculty and teachers collaborate in planning and carrying out programs to improve the level of science and math education in North Carolina. Science House programs include student programs, teacher workshops, and school visitation programs that cover the entire state.

Program Evaluation

All of the teachers involved in the Rural Schools Teacher Program met one day in May 1994 for a videotaped evaluation session. Several of their insights are listed below.

- Both the high- and low-achieving students are excited and enthusiastic about using computers in the classroom and laboratory. They become actively engaged in doing the laboratory investigations.
- Teachers like to use the equipment but are concerned about its scheduling and availability to fit the flow of their course schedule.

They are also concerned that the lab exercises meet the curriculum and prepare the students for the state end-of-course tests.

- Teachers need time and extra effort to set up, prepare, and take down the equipment. The support role of the HHMI master teacher, Judy Powell, is important in assisting the teachers and supporting the use of the equipment.
- Teachers see a need for balance of traditional, low-tech, and high-tech laboratory experiences. The balance addresses the limited resources of the schools and time constraints with the use of traveling equipment.

The program was evaluated through surveys conducted during and after the 1993 summer institute. The in-depth survey was conducted by staff of the Center for Research in Mathematics and Science Education at the University.

The teachers rated the summer workshop highly. Even though they perceived the content as very challenging, they consistently gave their summer experience high marks on different factors. Not only did they perceive the learning as a very beneficial experience, but there were some indications that the teachers are beginning to change from a teacher-centered method of teaching to one that is student centered.

When asked what to plan for the second summer institute, teachers requested more introductory information modules and use of technology. They recommended the following changes: (1) spend at least one day on computer instruction, (2) provide more examples of high-tech laboratory exercises for guidance at the start of the workshop, and (3) assist with developing additional labs to directly correlate with the new state-mandated science objectives.

These concerns were addressed during the 1994 summer institute. In addition, there was emphasis on teachers training other teachers and the production of modules that required less laboratory time. All of the labs used some discovery learning and a student-directed approach to develop concepts in biology, chemistry, and physics.

Program Director

William C. Grant, Ph.D
Associate Provost for Special Projects and Coordinator of African American Affairs
Box 7101
North Carolina State University
Raleigh, NC 27695-7101
(919) 515-7966
(919) 515-3750 (fax)
SPRWCG@PEELE.BAS.NCSU.EDU (E mail)

Institutional Profile

Total enrollment	27,170
Undergraduate enrollment	18,644
Number of faculty members	1,481
Endowment (millions)	$62
Annual budget (millions)	$545

Assessing Outreach Programs
University of Chicago

The University of Chicago is a private research institution in Chicago, Illinois. In 1989 the Howard Hughes Medical Institute awarded the University $2,000,000 to (1) develop new, advanced laboratory curricula for science majors in molecular and developmental biology, genetics, biochemistry, and related fields; (2) provide opportunities for collaborative research between University science faculty and students at two- and four-year schools, including minority institutions; (3) create introductory biology and chemistry courses to interest potential majors in biomedical sciences; and (4) expand a program to offer advanced summer training in biology, mathematics, chemistry, and physics to Chicago high school teachers.

A Long-Term Commitment

The University of Chicago has been committed to evaluating its Summer Seminars for High School Teachers since the program began 10 years ago. As early as the design phase, selected Chicago high school teachers were questioned about what form of continuing education was necessary to improve and refine their teaching skills.

Through the questionnaire, Dr. Laura Bornholdt, Special Assistant to the President of the University, designed monthlong seminars to be offered in the summer when the teachers' attention was at its peak. Dr. Bornholdt's emphasis on teacher feedback and assessment has set the tone for the 10 years that she has overseen the program; each summer a formal questionnaire is administered to participants, usually before and always at the end of the seminar. One evaluation even included a questionnaire six months later to determine how teaching practices had been modified as a result of the seminars.

The long-term goal of the seminars is to invigorate Chicago area public high school teachers by exposing them to new material they can adapt for their students, 85 percent of whom are underrepresented minorities. There are about 20 participants in each four-week seminar. Each of the seven seminars covers a separate academic discipline, ranging from earth sciences to writing. The HHMI grant has supported two of the seminars, Developmental Biology and Mathematics, since 1989.

Most seminars are held five days a week during July, and participants are invited to monthly lectures at the campus throughout the next academic year. Participants receive a stipend and are eligible to apply for credit toward a pay increase with the Chicago public school system. The curriculum is developed by the instructor, who is also responsible for screening applications and selecting participants.

"Teachers are really excited, animated and enthusiastic. They are sharing ideas with each other because of the participatory nature of the courses. It is a model for how they might teach in their schools," said Dr. Robert Perlman, Master, Biological Sciences Collegiate Division, and HHMI program director.

The developmental biology seminar has been taught since 1991 by Dr. Malka Moscona, Associate Professor, Biological Sciences Collegiate Division. The interdisciplinary nature of developmental biology is used as a stepping stone to explore almost all areas of modern biology—genetics, molecular biology, embryology, immunology, and virology. Dr. Moscona covers the fundamentals, such as meiosis, mitosis, and DNA transcription, in lectures and discussions at least three times a week. She is committed to reinforcing the basics of biology because she feels that "a good grounding in the basics gives teachers the flexibility to constantly adapt their approaches in the face of new ideas."

The remainder of the class time is devoted to the development of laboratory exercises, computer skills, library work, and interaction between participants. In addition, guest lecturers from the University are invited about once a week to elaborate on such topics as AIDS, cancer, and the development of the immune system. Dr. Moscona contends that her goal is to make the teachers into lifelong learners and to stimulate them to learn for pleasure. She has been consistently rated near the top of the rating scale by her participants.

The goal of Professor Robert Fefferman is to encourage the teaching of mathematics the way it is done in the mathematics seminar. "What's important is to teach that mathematics requires thinking about things, not mechanically grinding out lots of formulas," said Dr. Fefferman. The focus of the seminar is on calculus and its applications, with morning lectures covering such topics as cardinality, functions, limits, integrals, and infinite series. By afternoon, the participants are ready to separate into small groups to solve problems together. A unique feature of the course is that half of the participants are teachers and the other half are advanced high school students.

Evaluation Procedures

The seminar evaluations by the participants are valuable to the faculty as well as to Dr. Bornholdt, who uses them to assess faculty performance. The faculty use the evaluations to make refinements in their teaching style, curriculum, and seminar structure. For example, Dr. Moscona has restructured her seminar to devote more time to the development of laboratory exercises and computer competency. She has also built in more time for the teachers to interact with one another in experimenting with new ideas for teaching.

Several years ago, when high school students were brought in to provide feedback about laboratory exercises and lesson plans, the evaluations revealed the student presence to be so inhibiting that Dr. Moscona discontinued the practice Instead, she invited teachers to return later in the fall to present their lesson plans to one another.

On the other hand, student participation in the mathematics seminar was not found to be detrimental, in part because the teachers were encouraged to bring their best students, with whom they enjoyed good working relationships. The evaluations are also used to support requests for greater resources, enabling Dr. Moscona, for example, to secure more laboratory time and supplies from the university.

The evaluations at the end of the seminar ask the participants to rate such factors as the quality of the teaching, the organization of the course, the utility of the background materials, the novelty and rigor of the subject matter, and expectations about applying what they have learned to the classroom. In addition to an actual rating scale, the evaluation questionnaire usually requires written appraisals of the seminar and recommendations for seminar revisions.

Each year the seminar evaluations are designed, administered, analyzed, and compiled into a report by an independent evaluator, usually a graduate stu-

The University of Chicago Program of Continuing Education in Biology for Chicago Area High School Teachers, 1993–1994

- **What the Immune System Can Do For You and What You Can Do For Your Immune System**
  José Quintans
  Professor in the Department of Pathology
- **Biopsychology: Mind and Body**
  Martha McClintock
  Professor in the Department of Psychology, and Chairperson for the Committee on Biopsychology
- **The Human Genome Project and Ethical Issues Related to It**
  Mary Mahowald
  Professor in the Department of Obstetrics and Gynecology
- **Primate Behavior: Species Diversity, Ecological Variability and Lifetime Flexibility**
  Jeanne Altmann
  Professor in the Department of Ecology and Evolution and the Committee on Biopsychology
- **Exploring the Sahara for Dinosaurs**
  Paul Sereno
  Associate Professor in the Department of Organismal Biology and Anatomy
- **How Stress Proteins Help You Cope**
  Martin Feder
  Professor in the Department of Organismal Biology and Anatomy and the Committee on Evolutionary Biology
- **Multi-Media Computing: New Dimensions for the Neurosciences in the Classroom**
  Frank Hughes
  Professor in the Department of Anatomy
  Rush Presbyterian Medical Center
- **The Development of the Mammalian Blood Cells**
  Celeste Simon
  Assistant Professor in the Department of Pediatrics and Molecular Genetics and Cell Biology

dent in the University's Irving B. Harris Graduate School of Public Policy Studies. Hiring an HHMI-supported evaluator who is both independent of and unfamiliar with the program is considered to be an asset by Dr. Bornholdt. "We like to have the evaluation done by someone outside the program, and we like frequent changes in the evaluator and the evaluation instrument. Frequent changes keep our evaluators alert, and they are challenged to do a better evaluation than their predecessors. The same evaluator makes for too cozy a relationship to the program," she said.

A Follow-up Evaluation

The most extensive evaluation was that undertaken by graduate researcher Debra Haas for the 1992 Summer Seminars. Ms. Haas not only administered a questionnaire to 116 participants before and immediately after each seminar, she also followed up six months later with another questionnaire designed to gauge changes in teacher behavior after returning to the classroom.

By comparing the six-month findings with those immediately after the course, she found that the participants had slightly surpassed their own expectations. For example, while 68 percent of respondents attending one of the seven seminars thought they would change their curricular focus immediately after the seminar, 73 percent actually reported making changes.

Biology seminar participants, in particular, reported a variety of changes as a direct result of having taken the seminar. Seventy percent reported changing their curricular focus, 67 percent reported changing student assignments, and 30 percent reported evaluating student performance differently. Teachers also reported spending less time lecturing. While they reported using laboratory work slightly less often, they devoted more of the class time to group work.

The six-month follow-up evaluation was considered very valuable by Dr. Bornholdt, but expensive. If more resources were available, she w ld like to do this every year and possibly attempt to evaluate whether the modifications teachers attribute to their summer training are indeed beneficial to students.

The students at Oak Park River Forest High School, where Sam Manola teaches biology, are likely to benefit from the newly found enthusiasm of their teacher. "I learned to appreciate learning for the sheer pleasure of learning. My approach to learning had stagnated, but working with the many people at the university revived the joy....The seminar gave me the push I needed to try some things I had been afraid to try in the past," wrote Mr. Manola.

Program Director

Robert L. Perlman, M.D., Ph.D.
Master, Biological Sciences Collegiate Division
University of Chicago
Biological Sciences Learning Center
924 East 57th Street, Room 104A
Chicago, IL 60637-5415
(312) 702-7963
(312) 702-2254 (fax)

Institutional Profile

Total enrollment	9,809
Undergraduate enrollment	3,382
Number of faculty members	1,217
Endowment (billions)	$1.2
Annual budget (millions)	$729

238

Villanova University is a private comprehensive institution in Villanova, Pennsylvania. In 1991 the Howard Hughes Medical Institute awarded the University $650,000 to support a program to (1) enable undergraduates, especially those from groups underrepresented in the sciences, to receive special faculty tutoring in the sciences and participate in summer and academic-year research in laboratories on campus; (2) appoint two new faculty scientists, one in quantitative biology and the other in cellular and molecular biology; (3) enhance the laboratory component of the biology curriculum that will strengthen connections between the life sciences and other areas such as mathematics and computer sciences; and (4) provide outreach to Philadelphia high schools, to include summer and academic year enrichment for students and workshops and a "footlocker" program to provide teachers with equipment and software for new classroom experiments in modern biology.

The Summer Enrichment Program

Since 1992, 40 10th- and 11th-grade students have come to the Villanova University campus for a six-week summer enrichment program in biology and mathematics, supported in part by the Institute. The program, formally known as the Villanova–HHMI–NSF Young Scholars Program, is also funded through a grant from the National Science Foundation to Dr. William M. Fleischman, Professor of Computing Sciences, and Dr. Russell M. Gardner, Professor of Biology. The program consists of courses, laboratories, lectures, and field trips organized around one topic, with academic year follow-up activities such as research projects and symposia.

One of the summer research activities is a "graveyard tour" during which students visit historical graveyards in the Philadelphia area and collect data to compare 18th, 19th, and 20th century mortality rates and life expectancies. Since several of the graveyards are associated with identifiable population groups—African Americans at Mt. Gilead cemetery and Mennonites at Weaverland cemetery—students are able to explore differences in life expectancy among those groups.

"The important historical and social dimensions of this activity are not lost on the students," noted Dr. R. William Marks, Professor of Biology and HHMI program director. "When they inquire, at Mt. Gilead, why there are individuals for whom neither birth date nor age is recorded, they make direct contact with a historical reminder of slavery. And at Weaverland, seeing the prevalence of infant mortality among the Mennonites is something students do not easily forget."

The goal of the summer program is not simply to improve the technical skills and know-how of the high school students, many of whom are young women and members of underrepresented minorities, according to Dr. Marks. It also includes nurturing their sense of belonging to a "learning community." This achievement is signaled in part by their willingness to stay in touch with one another long after they have gone home, completed high school, and dispersed to colleges and universities all over the country.

For example, Tamia Steele of the 1992 summer class returned to Villanova in 1993 to give a presentation during the program's symposium on independent research projects. Ms. Steele, an African American from a New York City high school that was described by her guidance counselor as a "war zone," talked about her own project investigating the development of positive and negative stereotypes among children between the ages of four and seven years. Her mother, who accompanied her to the symposium, said her daughter's participation in the summer program produced dramatic changes in her self-confidence as well as her educational and career perspectives. Ms. Steele has matriculated at the State University of New York at Buffalo.

Soraya Kernizan, Brooklyn Friends School, and David Mora, from Xaverian High School, Brooklyn, participate in the summer enrichment program in quantitative biology.

Program Assessment and Tracking

"Evaluation and tracking of our summer students is labor-intensive, but that may be the only effective way to do it," said Dr. Marks. "We spend a lot of time corresponding with them. I don't think there is a more elegant way to do this and still get good information." In addition to formal follow-up correspondence for the program, many of the summer students write to Villanova faculty to request letters of recommendation for college applications. All the students from the summer program are invited to report on their progress the following spring, particularly regarding research projects they may have taken back and continued at their high schools.

The high school students who come to Villanova's campus outside Philadelphia are very high caliber. Their interests typically extend beyond science and mathematics, so that heated debates about classical music, literature, politics, or sports are not unusual during their stay on the campus. In 1993, the program selected about 40 students from a pool of 1,000 applicants.

Finding Cohesiveness in a Diverse Group

About half the students in the summer enrichment program are from minority groups, and young women have been in the majority for both summers. Although most students come from the New York–Washington corridor and western Pennsylvania, occasionally students come from as far away as California.

"It's a wonderful melting pot of both rural and urban students. At first I thought this mixture of all types would be a recipe for not talking to each other," Dr. Marks said. "But in fact, the group is remarkably cohesive. They genuinely get along and enjoy the diversity. It helps that they're all very bright and very interested in science."

Most of them continue to do well after they complete the program. For instance, of the 37 students who spent the summer of 1992 at Villanova, four are now attending Harvard University and three, the Massachusetts Institute of Technology. Of the 1993 group, four are at Harvard.

At the end of the session, students are given open-ended questionnaires to complete. "We expected the students to give one-sentence answers, but they wrote a lot about what worked for them and what didn't," Dr. Marks said. This information is taken very seriously. For example, in response to the students' comments, the Villanova group has introduced more structure to the dormitory routines. In addition, improvements are being made in the summer research projects because some students indicated they were "frustrated too much of the time."

Ties as a Tracking Mechanism

The real key to successful follow-up of the summer students, however, is the development of personal ties among the students and with the Villanova faculty members who serve as their mentors during the six-week session. These personal ties typically become the basis for one of the students to appoint him- or herself "recording angel" for the whole group, said Dr. Fleischman.

The recording angel works informally, telephoning other students, contacting them by conventional mail, or on the Internet by electronic mail. Informal use of electronic mail has proved so effective a means of communication that the program is seeking a way of extending this opportunity to all participants in the summer programs, but so far this has not been an easy undertaking.

For the time being, traditional communications and the informal student networks are the mainstay of Villanova's tracking efforts. Although the program uses standard procedures to follow up the students, those involved in the program find that the more time-consuming efforts enrich tremendously the quality of the tracking information. That is because the students share much more among themselves through informal contacts than by more standard techniques. The information is then transmitted to the program by the recording angel.

Dr. Fleischman pointed with pride to Oleg Drozhinin, who became the surprise recording angel for the 1992 summer group. "No one seemed a less likely candidate," Dr. Fleischman recalled. "He and his family are recent immigrants. Although he's very bright, he was very reticent and almost wary of us while he was here. But a year later, out of the blue he called and spent almost an hour on the phone with news about all the students in his class he had contacted. Now we hear from him at least a couple of times during the year." The shy high school computer whiz of a few years ago is studying biology at the Massachusetts Institute of Technology, Dr. Fleischman added.

Program Director

R. William Marks, Ph.D.
Associate Professor
Department of Biology
Villanova University
Villanova, PA 19085-1699
(215) 645-4830

Institutional Profile

Total enrollment	9,224
Undergraduate enrollment	7,260
Number of faculty members	545
Endowment (millions)	$25
Annual budget (millions)	$132

BEST COPY AVAILABLE

Attendees, Program Directors Meeting, October 3–5, 1994

Mary Mennes Allen, Ph.D.
Wellesley College

William Vail Allen, Ph.D.
Humboldt State University

G. Samuel Alspach, Jr., Ph.D.
Western Maryland College

Pamela Baker, Ph.D.
Bates College

Nancy T. Barnes, Ph.D.
University of North Carolina at Chapel Hill

Carol Bender, M.S.S.S.
University of Arizona

David H. Benzing, Ph.D.
Oberlin College

Sarah B. Berenson, Ph.D.
North Carolina State University

William E. Brown, Ph.D.
Carnegie Mellon University

Peter J. Bruns, Ph.D.
Cornell University

JW Carmichael, Ph.D.
Xavier University of Louisiana

Orville Chapman, Ph.D.
University of California–Los Angeles

Linda Chaput
Interactive Services

Hillel J. Chiel, Ph.D.
Case Western Reserve University

Jose M. Cimadevilla, Ph.D
St. Mary's University

Casey Clark, M.Ed.
Smith College

James P. Collins, Ph.D.
Arizona State University

Edward C. Cox, Ph.D.
Princeton University

David T. Crowther, M.Ed.
University of Nebraska–Lincoln

Martha A. Crunkleton, Ph.D.
Bates College

John Dewood David, Ph.D.
University of Missouri–Columbia

Eric Davies, Ph.D.
University of Nebraska–Lincoln

Ellen M. Dawley, Ph.D.
Ursinus College

Mark William Dubin, Ph.D.
University of Colorado at Boulder

Frederick A. Eiserling, Ph.D.
University of California–Los Angeles

Ross S. Feldberg, Ph.D.
Tufts University

William M. Fleischman, Ph.D.
Villanova University

Juan López Garriga, Ph.D.
University of Puerto Rico Mayaguez Campus

Stephen George, Ph.D.
Amherst College

Julie Graf
University of Colorado at Boulder

William C. Grant, Ph.D.
North Carolina State University

Sandra Gregerman, M.S.
University of Michigan Ann Arbor

Joseph Griswold, Ph.D.
City University of New York
City College

Stephen C. Harrison, Ph.D.
Harvard University

Carla Hass, Ph.D.
Pennsylvania State University

Anne M. Heinz, Ph.D.
University of Chicago

H. Craig Heller, Ph.D.
Stanford University

J.H.M. Henderson, Ph.D.
Tuskegee University

Cindy Henk
Louisiana State University and
A&M College

Susan A. Henry, Ph.D.
Carnegie Mellon University

Jacqueline Hunter, Ph.D.
Xavier University of Louisiana

Louis N. Irwin, Ph.D.
University of Texas at El Paso

John R. Jungck, Ph.D.
Beloit College

Lynne Kiorpes, Ph.D.
New York University

Steven A. Kolmes, Ph.D.
Hobart and William Smith Colleges

Deidre D. Labat, Ph.D.
Xavier University of Louisiana

Jay B. Labov, Ph.D.
National Research Council

Juan G. González Lagoa, Ph.D.
University of Puerto Rico
Mayaguez Campus

Sondra G. Lazarowitz, Ph.D.
University of Illinois at
Urbana–Champaign

Clarence M. Lee, Ph.D.
Howard University

Shin Lin, Ph.D.
Johns Hopkins University

Thomas S. Litwin, Ph.D.
Smith College

Daniel V. Lynch, Ph.D.
Williams College

R. William Marks, Ph.D.
Villanova University

Patricia A. Marsteller, Ph.D.
Emory University

Michael M. Martin, Ph.D.
University of Michigan–Ann Arbor

Karl R. Mattox, Ph.D.
Miami University

James Maurer
Interactive Services

Joyce B. Maxwell, Ph.D.
California State University–Northridge

Mark G. McNamee, Ph.D.
University of California–Davis

B.D. Mehrotra, Ph.D.
Tougaloo College

Bette Nicotri, Ph.D.
University of Washington

David J. Njus, Ph.D.
Wayne State University

Robert H. Parsons, Ph.D.
Rensselaer Polytechnic Institute

Carlton W. Paulson, Ph.D.
Concordia College at Moorhead

Robert L. Perlman, M.D., Ph.D.
University of Chicago

Andrew J. Petto, Ph.D.
University of Wisconsin–Madison

Herbert Posner, Ph.D.
State University of New York
at Binghamton

Steven W. Rissing, Ph.D.
Arizona State University

Frederick B. Rudolph, Ph.D.
Rice University

Exyie C. Ryder, Ph.D.
Southern University and A&M College
at Baton Rouge

Jeffrey A. Sands, Ph.D.
Lehigh University

Barbara Sawrey, Ph.D.
University of California–San Diego

R. Steven Schiavo, Ph.D.
Wellesley College

C. Thomas Settlemire, M.S., Ph.D.
Bowdoin College

Peter R. Shank, Ph.D.
Brown University

Harold Silverman, Ph.D.
Louisiana State University and
A&M College

Helene Slessarev, Ph.D.
Wheaton College

Dennison Smith, Ph.D.
Oberlin College

B.G. Stephens, Ph.D.
Wofford College

H. Eldon Sutton, Ph.D.
University of Texas at Austin

Anna Tan–Wilson, Ph.D.
State University of New York at
Binghamton

Sheila Tobias
The Research Corporation

José M. Veláquez, Ph.D.
University of Puerto Rico
Cayey University College

Merna Villarejo, Ph.D.
University of California–Davis

Graham C. Walker, Ph.D.
Massachusetts Institute of Technology

John E. Walsh, Ph.D.
Dartmouth College

Claudia Washburn
University of Illinois at
Urbana–Champaign

James J. Watrous, Ph.D.
Saint Joseph's University

Michael A. Wells, Ph.D.
University of Arizona

Richard A. White, Ph.D.
Duke University

Gabriele Wienhausen, Ph.D.
University of California–San Diego

Paul H. Williams, Ph.D.
University of Wisconsin–Madison

Scot A. Wolfe
Harvard University

Robert J. Wyman, Ph.D.
Yale University

Steven J. Zottoli, Ph.D.
Williams College

246

Awardee Institutions by Carnegie Classification, 1989–1994[1]

The Carnegie Foundation for the Advancement of Teaching classifies colleges and universities on the basis of such factors as the range of the baccalaureate program, number of Ph.D. degrees awarded annually, and amount of annual federal support for research and development, as appropriate. The Institute's assessments of institutions for the 1989–1994 competitions were based on the 1987 Carnegie Foundation classifications and included the following classifications and categorical definitions for public and private institutions:

Research Universities I: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate degree, and give high priority to research. They receive annually at least $33.5 million in federal support and award at least 50 Ph.D. degrees each year.

Research Universities II: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate degree, and give high priority to research. They receive annually between $12.5 million and $33.5 million in federal support for research and development and award at least 50 Ph.D. degrees each year.

Doctorate-Granting Universities I: In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctorate degree. They award at least 40 Ph.D. degrees annually in five or more academic disciplines.

Doctorate-Granting Universities II: In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctorate degree. They award annually 20 or more Ph.D. degrees in at least one discipline or 10 or more Ph.D. degrees in three or more disciplines.

Comprehensive Universities and Colleges I: These institutions offer baccalaureate programs and, with few exceptions, graduate education through the master's degree. More than half of their baccalaureate degrees are awarded in two or more occupational or professional disciplines such as engineering or business administration. All of the institutions in this group enroll at least 2,500 students.

Comprehensive Universities and Colleges II: These institutions award more than half of their baccalaureate degrees in two or more occupational or professional disciplines, such as engineering or business administration, and many also offer graduate education through the master's degree. All of the colleges and universities in this group enroll between 1,500 and 2,500 students.

Liberal Arts Colleges I: These highly selective institutions are primarily undergraduate colleges that award more than half of their baccalaureate degrees in arts and science fields.

Liberal Arts Colleges II: These institutions are primarily undergraduate colleges that are less selective and award more than half of their degrees in liberal arts fields. This category also includes a group of colleges that award less than half of their degrees in liberal arts fields but, with fewer than 1,500 students, are too small to be considered comprehensive.

Schools of Engineering and Technology: The institutions in this category award at least a bachelor's degree in programs limited almost exclusively to technical fields of study.

1 Further information may be found in Carnegie Foundation for the Advancement of Teaching *Classification of Institutions of Higher Education*, Princeton, New Jersey, 1987

Research Universities I

Boston University
California Institute of Technology
Carnegie Mellon University
Case Western Reserve University
Colorado State University
Columbia University
Cornell University
Duke University
Georgia Institute of Technology
Harvard University
Howard University
Indiana University at Bloomington
Johns Hopkins University
Louisiana State University
and A & M College
Massachusetts Institute of Technology
Michigan State University
New York University
North Carolina State University
The Ohio State University
Main Campus
Oregon State University
Pennsylvania State University
Main Campus
Princeton University
Purdue University Main Campus
Rutgers the State University of
New Jersey New Brunswick Campus
Stanford University
State University of New York at
Stony Brook
Texas A & M University
University of Arizona
University of California–Berkeley
University of California–Davis
University of California–Irvine
University of California–Los Angeles
University of California–San Diego
University of Chicago
University of Cincinnati Main Campus
University of Colorado at Boulder
University of Georgia
University of Hawaii at Manoa
University of Illinois at Chicago
University of Illinois at
Urbana-Champaign
University of Iowa
University of Kentucky
University of Maryland College Park
University of Miami
University of Michigan–Ann Arbor
University of Minnesota–Twin Cities
University of Missouri–Columbia
University of New Mexico
Main Campus
University of North Carolina at
Chapel Hill
University of Pennsylvania
University of Pittsburgh Main Campus
University of Rochester
University of Southern California
University of Tennessee, Knoxville
University of Texas at Austin
University of Utah
University of Virginia
University of Washington
University of Wisconsin Madison
Vanderbilt University
Washington University
Yale University

Research Universities II

Arizona State University
Auburn University
Brandeis University
Brown University
Emory University
Georgetown University
Iowa State University
Kansas State University
Oklahoma State University
Main Campus
Rensselaer Polytechnic Institute
State University of New York at Albany
State University of New York at Buffalo
Temple University
University of California–Santa Barbara
University of Delaware
University of Kansas Main Campus
University of Massachusetts
at Amherst
University of Nebraska–Lincoln
University of Oregon
University of South Carolina–Columbia
Utah State University
Washington State University
Wayne State University
West Virginia University

Doctorate-Granting Universities I
Catholic University of America
College of William and Mary
Illinois Institute of Technology
Lehigh University
Marquette University
Miami University
Rice University
State University of New York at Binghamton
Texas Tech University
Tufts University
University of Arkansas Main Campus
University of California–Santa Cruz
University of Notre Dame

Doctorate-Granting Universities II
Dartmouth College
Mississippi College
Rutgers the State University of New Jersey Newark Campus
Stevens Institute of Technology
University of Nevada
University of New Orleans
University of North Dakota
University of South Dakota
University of Vermont

Comprehensive Universities and Colleges I
California State University–Long Beach
California State University–Los Angeles
California State University–Northridge
Calvin College
Canisius College
City University of New York Brooklyn College
City University of New York City College
City University of New York Herbert H. Lehman College
City University of New York Hunter College
City University of New York Queens College
Concordia College at Moorhead
Fort Lewis College
Hampton University
Humboldt State University
Jackson State University
Manhattan College
San Diego State University
Saint Joseph's University
St. Mary's University
Southern University and A&M College at Baton Rouge
Tuskegee University
University of Puerto Rico Cayey University College
University of Puerto Rico Mayaguez Campus
University of Puerto Rico Rio Piedras Campus
University of Scranton
University of Texas at El Paso
University of Texas at San Antonio
Villanova University

Comprehensive Universities and Colleges II
Clark Atlanta University
Illinois Benedictine College
Xavier University of Louisiana

Liberal Arts Colleges I
Amherst College
Antioch University
Barnard College
Bates College
Beloit College
Bowdoin College
Bryn Mawr College
Carleton College
Centre College
Colby College
Colgate University
College of the Holy Cross
Colorado College
Eckerd College
Gettysburg College
Goucher College
Hamilton College
Haverford College
Hobart and William Smith Colleges
Hope College
Juniata College
King College
Knox College
Lafayette College
Lawrence University

Nebraska Wesleyan University
Oberlin College
Reed College
Saint Olaf College
Smith College
Swarthmore College
Union College
University of the South
Ursinus College
Wellesley College
Wesleyan University
Western Maryland College
Wheaton College
Williams College

Liberal Arts Colleges II
Fisk University
Hiram College
Morehouse College
Ohio Wesleyan University
Spelman College
Tougaloo College
Wofford College

Schools of Engineering and Technology
Cooper Union
Harvey Mudd College

250

Awardee Minority Institutions, 1989–1994

In the assessment of institutions for the 1991 and 1993 undergraduate grants competitions, the Institute has taken into account the institutions' records of graduating in the sciences students from minority groups underrepresented in scientific fields. Information for these assessments has been provided by the following sources:

The Minority Access to Research Careers Program of the National Institutes of Health. (This program was created in 1977 by the National Institute of General Medical Sciences to increase the number of biomedical scientists from minority groups.)

The Minority Biomedical Research Support Program of the National Institutes of Health. (This program was established in 1972 by the NIH Division of Research Resources to develop minority student, faculty, and institutional involvement in biomedical research.)

The National Association for Equal Opportunity in Higher Education. (This organization, founded in 1969, represents and serves some 117 historically and predominantly black colleges and universities.)

The Office of Civil Rights of the U.S. Department of Education. (This federal agency is responsible for analyzing and disseminating data on minority students at the nation's colleges and universities, including the number of degrees conferred, as submitted through the Integrated Post Secondary Education System and required of all institutions.)

Historically Black Institutions

Clark Atlanta University
Fisk University
Hampton University
Howard University
Jackson State University
Morehouse College
Southern University
and A&M College at Baton Rouge
Spelman College
Tougaloo College
Tuskegee University
Xavier University of Louisiana

Institutions with Significant Underrepresented Minority Student Presence in the Sciences

California State University–
Long Beach
California State University–
Los Angeles
City University of New York
Brooklyn College
City University of New York
City College
City University of New York
Herbert H. Lehman College
City University of New York
Hunter College
Fort Lewis College
Mississippi College
St. Mary's University
University of Puerto Rico
Cayey University College
University of Puerto Rico
Mayaguez Campus
University of Puerto Rico
Rio Piedras Campus
University of Texas at El Paso
University of Texas at San Antonio

Awardee Institutions by State, 1989–1994

Alabama
Auburn University, Auburn University
Tuskegee University, Tuskegee

Arizona
Arizona State University, Tempe
University of Arizona, Tucson

Arkansas
University of Arkansas Main Campus, Fayetteville

California
California Institute of Technology, Pasadena
California State University–Long Beach
California State University–Los Angeles
California State University–Northridge
Humboldt State University, Arcata
Harvey Mudd College, Claremont
San Diego State University, San Diego
Stanford University, Stanford
University of California–Berkeley
University of California–Davis
University of California–Irvine
University of California–Los Angeles
University of California–San Diego, La Jolla
University of California–Santa Barbara
University of California–Santa Cruz
University of Southern California, Los Angeles

Colorado
Colorado College, Colorado Springs
Colorado State University, Fort Collins
Fort Lewis College, Durango
University of Colorado at Boulder

Connecticut
Wesleyan University, Middletown
Yale University, New Haven

Delaware
University of Delaware, Newark

District of Columbia
Catholic University of America
Georgetown University
Howard University

Florida
Eckerd College, St. Petersburg
University of Miami, Coral Gables

Georgia
Clark Atlanta University, Atlanta
Emory University, Atlanta
Georgia Insitute of Technology, Atlanta
Morehouse College, Atlanta
Spelman College, Atlanta
University of Georgia, Athens

Hawaii
University of Hawaii at Manoa, Honolulu

Illinois
Illinois Benedictine College, Lisle
Illinois Institute of Technology, Chicago
Knox College, Galesburg
University of Chicago, Chicago
University of Illinois at Chicago
University of Illinois at Urbana–Champaign
Wheaton College, Wheaton

Indiana
Indiana University at Bloomington
Purdue University Main Campus, West Lafayette
University of Notre Dame, Notre Dame

Iowa
Iowa State University, Ames
University of Iowa, Iowa City

Kansas
Kansas State University, Manhattan
University of Kansas Main Campus, Lawrence

252

Kentucky
Centre College, Danville
University of Kentucky, Lexington

Louisiana
Louisiana State University and A&M College, Baton Rouge
Southern University and A&M College at Baton Rouge
University of New Orleans, New Orleans
Xavier University of Louisiana, New Orleans

Maine
Bates College, Lewiston
Bowdoin College, Brunswick
Colby College, Waterville

Maryland
Goucher College, Baltimore
Johns Hopkins University, Baltimore
University of Maryland, College Park
Western Maryland College, Westminster

Massachusetts
Amherst College, Amherst
Boston University, Boston
Brandeis University, Waltham
College of the Holy Cross, Worcester
Harvard University, Cambridge
Massachusetts Institute of Technology, Cambridge
Smith College, Northampton
Tufts University, Medford
University of Massachusetts at Amherst
Wellesley College, Wellesley
Williams College, Williamstown

Michigan
Calvin College, Grand Rapids
Hope College, Holland
Michigan State University, East Lansing
University of Michigan, Ann Arbor
Wayne State University, Detroit

Minnesota
Carleton College, Northfield
Concordia College at Moorhead
Saint Olaf College, Northfield
University of Minnesota–Twin Cities, St. Paul

Mississippi
Jackson State University, Jackson
Mississippi College, Clinton
Tougaloo College, Tougaloo

Missouri
University of Missouri–Columbia
Washington University, St. Louis

Nebraska
Nebraska Wesleyan University, Lincoln
University of Nebraska–Lincoln

Nevada
University of Nevada, Reno

New Hampshire
Dartmouth College, Hanover

New Jersey
Princeton University, Princeton
Rutgers the State University of New Jersey Newark Campus
Rutgers the State University of New Jersey New Brunswick Campus
Stevens Institute of Technology, Hoboken

New Mexico
University of New Mexico Main Campus, Albuquerque

New York
Barnard College, New York City
Canisius College, Buffalo
City University of New York Brooklyn College
City University of New York City College

City University of New York
Herbert H. Lehman College
City University of New York
Hunter College
City University of New York
Queens College
Colgate University, Hamilton
Columbia University, New York City
Cooper Union, New York City
Cornell University, Ithaca
Hamilton College, Clinton
Hobart and William Smith Colleges, Geneva
Manhattan College, Riverdale
New York University, New York City
Rensselaer Polytechnic Institute, Rensselaer
State University of New York at Albany
State University of New York at Binghamton
State University of New York at Buffalo
State University of New York at Stony Brook
Union College, Schenectady
University of Rochester, Rochester

North Carolina

Duke University, Durham
North Carolina State University, Raleigh
University of North Carolina at Chapel Hill

North Dakota

University of North Dakota, Grand Forks

Ohio

Antioch University, Yellow Springs
Case Western Reserve University, Cleveland
Hiram College, Hiram
Miami University, Oxford
Oberlin College, Oberlin
The Ohio State University
Main Campus, Columbus
Ohio Wesleyan University, Delaware
University of Cincinnati Main Campus, Cincinnati

Oklahoma

Oklahoma State University
Main Campus, Stillwater

Oregon

Oregon State University, Corvallis
Reed College, Portland
University of Oregon, Eugene

Pennsylvania

Bryn Mawr College, Bryn Mawr
Carnegie Mellon University, Pittsburgh
Gettysburg College, Gettysburg
Haverford College, Haverford
Juniata College, Huntington
Lafayette College, Easton
Lehigh University, Bethlehem
Pennsylvania State University
Main Campus, University Park
Saint Joseph's University, Philadelphia
Swarthmore College, Swarthmore
Temple University, Philadelphia
University of Pennsylvania, Philadelphia
University of Pittsburgh Main Campus
University of Scranton, Scranton
Ursinus College, Collegeville
Villanova University, Villanova

Rhode Island

Brown University, Providence

South Carolina

University of South Carolina–Columbia
Wofford College, Spartanburg

South Dakota

University of South Dakota, Vermillion

Tennessee

Fisk University, Nashville
King College, Bristol
University of the South, Sewanee
University of Tennessee, Knoxville
Vanderbilt University, Nashville

Texas

Rice University, Houston
St. Mary's University, San Antonio

Texas A & M University, College Station
Texas Tech University, Lubbock
University of Texas at Austin
University of Texas at El Paso
University of Texas at San Antonio

Utah
University of Utah, Salt Lake City
Utah State University, Logan

Vermont
University of Vermont, Burlington

Virginia
College of William and Mary, Williamsburg
Hampton University, Hampton
University of Virginia, Charlottesville

Washington
University of Washington, Seattle
Washington State University, Pullman

West Virginia
West Virginia University, Morgantown

Wisconsin
Beloit College, Beloit
Lawrence University, Appleton
Marquette University, Milwaukee
University of Wisconsin–Madison

Puerto Rico
University of Puerto Rico Cayey University College, Cayey
University of Puerto Rico Mayaguez Campus
University of Puerto Rico Rio Piedras Campus

Office of Grants and Special Programs Publications

General Publications

Grants for Science Education (annual)

Community Partnerships in Science Education, Washington, D.C., Metropolitan Area Precollege Science Education Initiatives (annual)

Meetings of Grantees

Graduate Education Fellows Meetings

Meeting of Medical Student Fellows, Program and Abstracts (annual)

Meeting of Predoctoral and Physician Postdoctoral Fellows, Program and Abstracts (annual)

Undergraduate Program Directors Meetings

Attracting Students to Science: Undergraduate and Precollege Programs, 1992

Enriching the Undergraduate Laboratory Experience, 1993

Institutional Strategies for Enhancing Undergraduate Science Education, 1993

Science Education: Expanding the Role of Science Departments, 1995

Precollege Science Education Program

Science Museums: Creating Partnerships in Science Education, 1994

Science Museums: Enlisting Communities in Science Education Partnerships, 1995

Holiday Lectures on Science (brochure) (annual)

Program Announcements

Graduate Science Education Program

Predoctoral Fellowships in Biological Sciences (annual)

Research Training Fellowships for Medical Students (annual)

Postdoctoral Research Fellowships for Physicians (annual)

Undergraduate Biological Sciences Education Program

Undergraduate Biological Sciences Education Program (annual)

Precollege and Public Science Education Program

Precollege Science Education Program (annual)

International Program

International Program (biennial)

Information Booklets

Graduate Science Education Program

Information for Medical Student Fellows and Fellowship Institutions (annual)

Information for Predoctoral Fellows and Fellowship Institutions (annual)

Information for Physician Postdoctoral Fellows and Fellowship Institutions (annual)

Undergraduate Biological Sciences Education Program

Information for Colleges and Universities Awarded Undergraduate Grants (annual)

Precollege and Public Science Education Program

Information for Science Museums and Biomedical Research Institutions Awarded Precollege Grants (annual)

International Program

Information for International Research Scholars and Grantee Institutions (biennial)

Research Resources for Medical Schools Program

Research Resources for Medical Schools Program

Program Directories

Graduate Science Education Program

Directory of Predoctoral Fellows

Directory of Medical Student Fellows

Directory of Physician Postdoctoral Fellows

Undergraduate Biological Sciences Education Program

Undergraduate Program Directory

Precollege Science Education Program

Precollege Science Education Program Directory

International Program

International Research Scholars Program Directory: Australia, Canada, Mexico, New Zealand, United Kingdom (available fall 1995)

Publications on the HHMI Grants Program may be requested from

Howard Hughes Medical Institute
Office of Grants and Special Programs
4000 Jones Bridge Road
Chevy Chase, MD 20815-6789
(fax) 301-215-8888
(phone) 301-215-8870

258

Officers

Purnell W. Choppin, M.D.
President

W. Maxwell Cowan, M.D., Ph.D.
Vice President and
Chief Scientific Officer

Joan S. Leonard, Esq.
Vice President and General Counsel

Joseph G. Perpich, M.D., J.D.
Vice President for
Grants and Special Programs

Jon C. Strauss, Ph.D.
Vice President and
Chief Financial Officer

Carter F. Wolfe
Vice President and
Chief Investment Officer

Principal Staff Members

Craig A. Alexander, Esq.
Deputy General Counsel

Stephen A. Barkanic
Grants Program Officer

W. Emmett Barkley, Ph.D.
Director of Laboratory Safety

Lillian H. Blucher
Managing Director–Investments

Winfred J. Clingenpeel
Director of Purchasing

Jill Conley, Ph.D.
Grants Program Officer

Barbara Filner, Ph.D.
Grants Program Officer

James R. Gavin III, M.D., Ph.D.
Senior Scientific Officer

Donald H. Harter, M.D.
Senior Scientific Officer and Director, HHMI-NIH Research Scholars Program

Heidi E. Henning, Esq.
Associate General Counsel

John A. Jones
Director of Computer Services

David W. Kingsbury, M.D.
Senior Scientific Officer

Edward H. Klees, Esq.
Associate General Counsel

Robert B. Kuhn III
Director of Human Resources

Dee Lord, Esq.
Associate General Counsel

Robert H. McGhee
Director of Research Facilities Planning

Alan E. Mowbray
Director of Management Services

Robert C. Mullins
Director of Internal Audit

Edward J. Palmerino
Assistant Controller

Robert A. Potter
Director of Communications

Ellen B. Safir
Managing Director–Investments

Mark W. Smith
Controller

Claire H. Winestock, Ph.D.
Senior Scientific Officer

Robert Yarbrough, Esq.
Associate General Counsel

260

Office of Grants and Special Programs

Joseph G. Perpich, M.D., J.D.
Vice President for Grants and Special Programs

Stephen A. Barkanic
Program Officer
Undergraduate Science Education Program

Jill Conley, Ph.D.
Program Officer
Precollege and Public Science Education Program
International Program

Barbara Filner, Ph.D.
Program Officer
Graduate Science Education Program
Research Resources Program

Yvonne P. Forsbergh
Program Analyst
Precollege and Public Science Education Program
International Program

Maryrose Franko, Ph.D
Program Analyst
Graduate Science Education Program

Gertrude B. Kelly
Editor
Grants Publications

Maria Koszalka
Program Analyst
Undergraduate Science Education Program

Mary McCormick, Ph.D.
Program Analyst
Graduate Science Education Program

Patricia Soochan
Program Analyst
Undergraduate Science Education Program

Keith Sopher
Program Analyst
Graduate Science Education Program

Tony Tse
Program Analyst
Precollege and Public Science Education Program
International Program

Rose A. Napper
Executive Secretary

Patricia A. Anderson
Senior Secretary

Jennifer Brehm
Senior Secretary

Jamie Holtzclaw Gresty
Senior Secretary

Moscow Office
Gregory M. Johnson
Program Coordinator
Eastern Europe and Former Soviet Union Initiative

Index

assessment, xiv, xxii–xxiii, 21, 27, 38, 59–60, 61–62, 63, 65–67, 67–68, 73, 74, 76–79, 80–82, 83–84, 85, 87, 127, 136, 159, 162–168, 170–171, 172, 175–176, 181, 183–188, 198, 201, 209–210, 211, 212–214, 217–218
- control groups, 61, 62, 63, 84, 164, 167–168
- database, 59, 60, 61, 159–160, 185
- evaluators, 32, 61, 63, 74, 78, 80–81, 163, 201, 213
- exit interview, 188

courses, 8
- biochemical techniques, xiii
- biology for elementary education majors, 37, 126–127
- chemical biology, 48
- computational biology, 73, 196
- computational chemistry, 73, 196
- computational geometry, 53
- computational molecular biology, 197
- developmental biology, 53
- introductory biology, 201
- introductory calculus, 57
- introductory chemistry, 184, 194, 201
- introductory physics, 72
- organic chemistry, 48, 55, 148
- x-ray crystallography, 55

curricular reform, 8
- approach, xxii, xxiii, 18, 19, 71–72, 74–75, 189–190, 202
- biochemistry, 74, 193
- biology, xxi, 8, 71–82, 192, 195
- chemistry, xxiii, xxiv, 8, 193–194, 195
- impact, 74
- issues, 71–74
- physics, 72
- resistance to, 18, 73
- teaching modules, 34, 192–208

educational technology, xii, xxiii, xxiv, 47, 53, 58, 83, 86, 99, 127, 142, 148, 152–153, 195, [illegible] 207
- biocomputation lab, 201
- biological imaging, 196
- chi-square analysis, 79
- communication, xviii, [illegible], 129, 130, 218, 219
- computer graphics, 48, 55, 58, 150
- computer modeling, 148, 150
- computer simulations, 53
- cost of, 51, 83
- curriculum modules, 48, 208
- digital videomicroscopy, [illegible]
- fractal analysis, 57
- graphical interfaces, 53
- image analysis workstation, 144
- interactive laboratory manuals, 56
- macromolecular modeling, 57
- mathematical models, 53
- morphology of nerve cells, 53
- multimedia theatre, 58
- multivariate statistics, 196
- neural networks, 53
- organization of virus particles, 55
- pattern formation, 53
- programs,
  - BioCalc, 57
  - BioNet, 31, 111, 161
  - BioQUEST, xiii, xix, 48, 50, 53, 142
  - DNA Inspector, 161
  - DNA Strider, 161
  - HyperCHEM, 48, 149
  - INHERIT, 143
  - Kinemage, 48, 50
  - MacClade, 147
  - Macmolecule, 161
  - MATHCAD, 136
  - Mathematica, 50, 57
  - NetSim, 53
  - NeuroSim, 53
  - Project LearnLink, 54
  - Quanta, 48
  - SequenceIt!, 143
- videoprobe microscopy, 55, 56
- videos, 128
  - *Inventing the Atom*, 150
- x-ray crystallography, 55

faculty involvement, xx, xxii, 6–7, 18–19, 24–26, 31, 37, 41–48, 59, 69, 70, 71, 85, 95, 96, 101, 105–106, 110, 116, 135, 152–158, 166, 191, 202

historically black colleges and universities, xxi, 25, 65, 93

interdisciplinary curricula, xx, xxi, 7, 18, 19, 45, 72, 73, 76, 81, 94, 174, 195, 202, 204, 212

laboratories
- biochemical techniques, 56
- BioComputation Lab, 201
- cardiovascular and respiratory systems, 100
- computer communications, 100
- computer modeling, 148, 150
- gases, 100
- physics for biologists, 127
- protein studies [illegible]

laboratory experience
- counselors, 100
- outreach, 79
- teachers, 100
- undergraduates, [illegible]

[illegible]

[illegible] 11, 20, 24, 79, 80, 93, 201, 212 mentoring, 31, 33, 62, 69, 81, 171, 195, 218

minority students in science, 23, 24, 29, 32, 35, 42, 51, 62, 63, 66, 70, 83, 85, 99, 100, 102, 170, 171, 179, 183, 184, 195, 202, 207, 211, 218
  African American, xxi, 23, 24, 65, 69, 79, 85, 93, 96, 131, 167–168, 169, 174, 181–182, 202, 217
  Hispanic 107, 131, 152, 202
  Native American, 41, 131, 140, 161, 202

outreach programs, 8–10, 84
  institutional levels
    community college faculty, 41, 43, 44, 130, 138
    community college students, 41–43, 134, 138
    elementary school administrators, 33, 35, 119
    elementary school counselors, 98
    elementary school students, 54, 56, 152
    elementary school teachers, 34, 54, 86, 98, 104, 110, 118, 129, 152
    entering freshmen, 147
    high school administrators, 33, 165, 206
    high school counselors, 98, 100
    high school students, 23, 24, 54, 56, 60, 68, 76, 79, 80, 93, 100, 102, 146, 152, 157, 206, 212, 218
    high school teachers, 48, 54, 76, 78, 86, 93, 98, 100, 104, 110, 129, 152, 155, 204, 207, 209, 211–212, 216
    kindergarten, 56, 75, 83, 86, 129, 152
    middle school administrators, 33, 35, 206
    middle school counselors, 98
    middle school students, 23, 54, 56, 60, 206
    [illegible]school teachers, 34, 54, 80, 81, 8[illegible] 110, 118, 129, 146, 152, 206
    precollege students, 65, 86, 147, 152, 157, 175, 204
    precollege teachers, 8, 86, 152, 157
    regional, 32
    rural, 47, 76, 81, 206, 209, 218
    transfer students, 41, 42–43, 44–45, 134, 138
    women, 9, 51, 61, 93, 169, 218
  issues
    budget issues, 32, 46
    commitment to, 32, 108
    enrollment impact, 32
    equipment purchase, 29, 43, 82, 105, 109
    faculty participation, 24, 94–104
    institutional commitment, 32–33
    precollege diversity, 84
    role of precollege administrators, 33, 101, 165
    tenure considerations, 26, 85, 96

programs
  Academic Advancement Program, 204
  Biomedical Honors Corps, 24
  Bionet, 31, 111, 161
  Bioscience Institute, 30, 104, 105, 108
  BioStar, 23, 93, 95
  Bridging the Gap, 113
  Chemical Education for Public Understanding Program (CEPUP), 118
  ChemStar, 23, 93, 95
  Current Students/Future Scientists and Engineers, 28, 98, 102–103
  Educational Nurturing of Highly Academic National Candidates for Excellence in Science, 174
  Fast plants, 32, 174
  First Year Minority Mentorships in Biology and Chemistry, 171
  Freshman Year, The, 136–137
  Full Option Science System (FOSS), 118
  Heron Network/Institute, 112
  Honors Undergraduate Research Program, 203
  Horizons Unlimited, 157
  Manduca Sexta Project, 157
  Marvelous Munching Melanoplus, 157
  MathStar, 23, 93, 95
  Med Start, 157
  Minority Access to Research Careers (MARC), 65
  Minority Biomedical Research Support (MBRS), 65
  National Diffusion Network, 137
  Nebraska Frameworks, 129
  Pathways for Women in Science, xvii, 61, 169
  Physics on the Road, 209
  Project 2061, 129
  Project LearnLink, 54
  Research Scholars Program, 122
  Rural Schools Teacher Program, 209
  Saturday Academies, 204
  Science and Mathematics Achievement for Research Training, 204
  Science Connection, 157
  Science Education Research Group (SERG), xxii, 24–26, 94, 95, 96
  Science Education Scholars Program, [illegible]
  Science House, 209
  Science Squad, 30, 104, 107–108
  Science on Wheels, 47, 152–153
  Smith Summer Science Program, 102–103
  Stress on Analytical Reasoning (SOAR), xxi, 24, 26–93
  Summer Enrichment Program, 169–171, 176
  Summer Science, 68
  Summer Science Academy, 23–26, 27
  Summer Science for High School Teachers, 211
  Summer Science Institute, 31–102

Summer Science Program for Minority Students, 184
Summer Seminars for High School Teachers, 78, 211
Teach for America, 125
Teacher/Pre-Service Teacher Research Experience, 157
Teaching Scholars Program, 35, 39, 121–123
Triple S, 24
Undergraduate Biology Education Program, 41
Undergraduate Biology Research Program, 59, 157–159
Undergraduate Research Opportunity Program, 65, 179
University Partnership Program, 138
Wisconsin Fast Plants Program, 32, 114–115, 174
Young Partnership Program, 138
Young Scholar Research Program, 147
Young Scholars Program, 216
Young Scholars Project in Biology and Mathematics, 79

recruitment and retention strategies, xvi, 29, 61, 66, 71, 93, 101, 117, 121, 175–176, 183, 185, 189, 202–204

research, 6, 8, 30, 63, 71, 79, 177, 217
independent, 71, 217

research areas
brain
hippocampus and rhythm, 180
disease
Lyme disease, 180
genes, activity
CREB, 178
p53, 166–167
ribosomal promoter, 178
Sp1, 178
genes, expression
luteinizing hormone releasing hormone, 158
p53, 177
immune system
role, 180
T cell maturation, 177
intracellular localization, 55
morphology of nerve cells, 53
natural products
delta lactone rings, 169
nervous system
alcohol effects, 158
Batten's disease, 178
embryonic development, 1[illegible]
menstruation, 180
morphology of nerve cells, 53
walking, 180
pancreatic cells
photodynamic therapy, 176
plants
sphingolipids, 186
specialized
transmission electron microscopy, 186
stereotypes, 217
theoretical genetics, 147
transcription
phosphorylation of factor, 178
virus
assembly, 55
interferon effects, 178

science centers and laboratories
Biology Learning Center, 157, 161
Center for Academic and Research Excellence, 203
Center for Biology Education, xxii, 31, 110
Center for Research in Mathematics and Science Education, 76
Clark Science Center, 28
Computer Training Center, 195
LEAD Center, 63
Math and Science Resource Center, 68, 185

science departments
community relationships, 34, 44, 45
course resources, 104
educational reform, xvi, 83
institutional differences, 84
organization, xvi, 73
role, 28, 30

science education
courses
advanced algebra/trigonometry, 204
AIDS, 114, 212
biotechnology, 102, 104, 107, 204
botany, 104
cancer, 114, 212
career exploration, 102, 204
cell biology, 110
combustion, 47, 132
conductivity, 47
DNA, 16, 104, 111, 123, 139, 212
drugs and the nervous system, 104
ecology, 104, 111, 114
ecosystems, 143
electronic instruments (music), 102
environment, 113, 204
enzymes, 112
extraterrestrial radiation, 111
fast plants, 113, 114
field trips, 129, 216
genetics, 110, 143, 204
geometry, 204
heart, 113
hornworms, 114
human diversity, 126
human genetics, 31
ice formation, 111

immune system, 212
instruments, 102
genetics, 110, 143, 204
lasers, 102
macromolecular structure, 48
meiosis, 110, 212
mitosis, 212
molecular and cell biology, 192
molecular biology, 104
neural networks, 55
plant biology, 113, 114
plant sciences 113
polymers, 102, 153
pre-calculus, 204
protein sequencing, 143
radon, 129
reproduction, 110
Scholastic Achievement Test, preparation for, 204
scientific method, 151
social stereotypes, 102
species interaction, 143
taste, 112
wetlands, 129
yeast , 104
instructors
graduate students, 33
master teachers, 32, 33, 104, 116
regional teams, 32
teaching assistants, 33, 36, 39, 40, 93, 121–125, 138
transfer students, 41, 43, 45
issues
attitudes toward, 16, 18, 83, 84
budget cutbacks, xvi
inquiry-based instruction, 42, 46
institutional support, 28, 32–33, 84
national standards, 83
partnerships, 34, 43, 114, 209
student selection, 68
teachers' needs, 106
teaching methods, 42–46, 49, 71

science literacy, xxiii, 17, 20–21, 63, 83, 84, 187

science teaching
issues
approaches, 34, 46, 71
challenges, 13
peer instruction, 40
preparation, 34
theory and practice, 56
instructors
biomedical science majors, 116

community college teachers, 41, 43, 44
elementary education majors, 34, 37, 40, 126
graduate students, 33, 36, 121
undergraduates, 105
upper-level undergraduates, 21, 34, 35, 40, 121

seminars
participants
educators, 7
high school teachers, 76, 78, 211
topics
biology, 211, 214
counseling, 137
ethics, 157
gender bias, 99
laboratory, 35
mathematics,78, 212
project development, 35
research methods, 147

women in science, xii, xiii, 29, 32, 51, 61, 62, 67–69, 70, 79, 83, 85, 98, 100, 101, 102, 123, 169, 179, 183, 190, 195, 218

workshops, 154
students
community college, 137
teachers, 48, 55, 76, 99, 104, 110–146, 206, 209
topics
bacterial transformation, 155
BioQUEST materials, 146
career development, 102
college admissions, 102
computer skills, 135
counselors, 99
curriculum design, 50, 146, 194
DNA electrophoresis, 104
educators, 128
electronic communication, 150
faculty, 7, 41
financial aid, 102
forensic botany, 104
gene cloning, 155
laboratory exercises, 42, 100, 133
molecular biology, 155
orientation, 24
physics teaching, 128
stream ecology, 104
teaching strategies, 39, 41, 42, 76, 84, 130–133
writing, 42, 135, 117, 179, 211
yeast, 104